NOAA Technical Report NOS CO-OPS 046

Humboldt Bay Current Surveys: December 2002 - October 2004

Silver Spring, Maryland
September 2005

noaa National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services
Products and Services Division

Center for Operational Oceanographic Products and Services
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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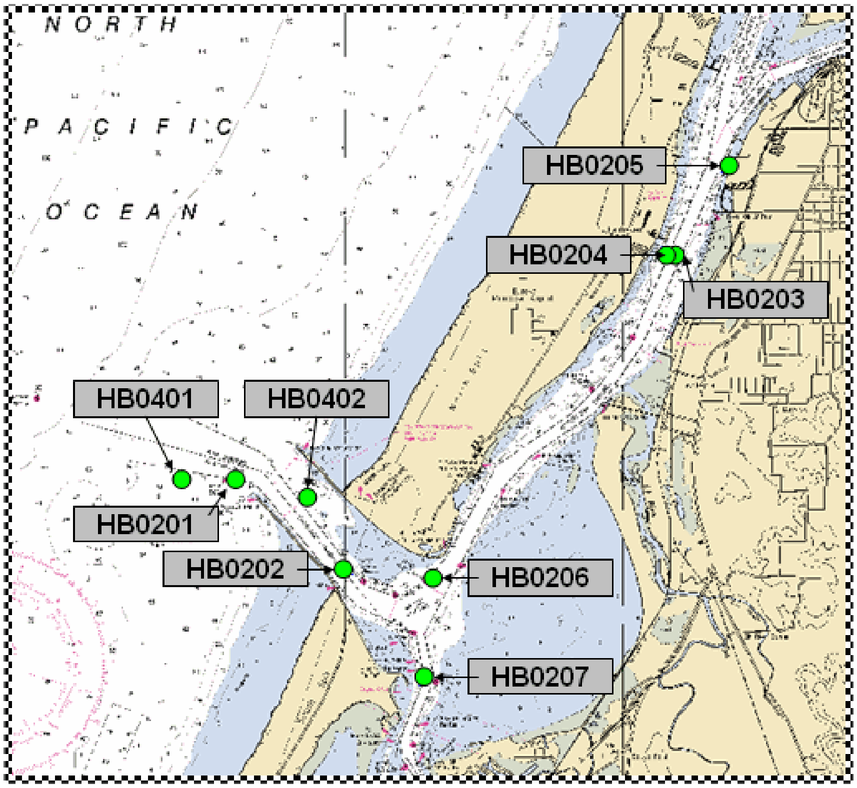

Humboldt Bay Survey Area

Karen Earwaker
September 2005

noaa **National Oceanic and Atmospheric Administration**

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LIST OF ACRONYMS AND ABBREVIATIONS

ADCP	Acoustic Doppler Current Profiler
ASCII	American Standard Code for Information Interchange
ATON	Aids to Navigation
cm/s	centimeters per second
CO-OPS	Center for Operational Oceanographic Products and Services
dir	direction in degrees True North
HA	29 day harmonic analysis
HBHD	Humboldt Bay Harbor District
kHz	kiloHertz
m	meters
MEC	Maximum Ebb Current
MFC	Maximum Flood Current
MLLW	mean lower low water
nm	nautical mile
NCOP	National Current Observation Program
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NW	northwest
NWLON	National Water Level Observation Network
NWS	National Weather Service
PORTS	Physical Oceanographic Real-Time System
QC	quality control
RDI	R.D. Instruments
RMS	root mean square
SL-ADP	side looking acoustic Doppler profiler
SNR	signal to noise ratio
SSE	south southeast
TRBM	trawl resistant bottom mounted
USACE	United States Army Corps of Engineers
UTC	Universal Time Coordinate

1.0 INTRODUCTION

At the request of the Humboldt Bay Harbor Recreation and Conservation District and the Humboldt Bay Pilots Association, the National Ocean Service's Center for Operational Oceanographic Products and Services (CO-OPS) conducted a series of current measurements within Humboldt Bay, California, under the auspices of the National Current Observation Program. The local user community reported that the currents differed in strength and timing from the existing published predictions that were referenced to San Francisco Bay Entrance and based on 7 days of 1923 pole data acquired 0.6nm south of Pt. Diablo. Mariners noted strong cross currents at the entrance to Humboldt Bay that tended to 'push' their vessel towards the north jetty during the winter. This first current survey of Humboldt Bay met CO-OPS mission to promote safe navigation and was conducted during the winter when conditions were expected to be most extreme, as requested by the Humboldt Bay Chief Executive Officer. A total of seven stations were occupied during the 2002-2003 survey: one station outside the harbor and six within the Bay (Figure 1). Prior to the 2002 survey, there were 5 stations within Humboldt Bay referenced to time and speed ratio offsets to SF Bay Entrance. CO-OPS' intention to make a new reference station near the entrance of Humboldt

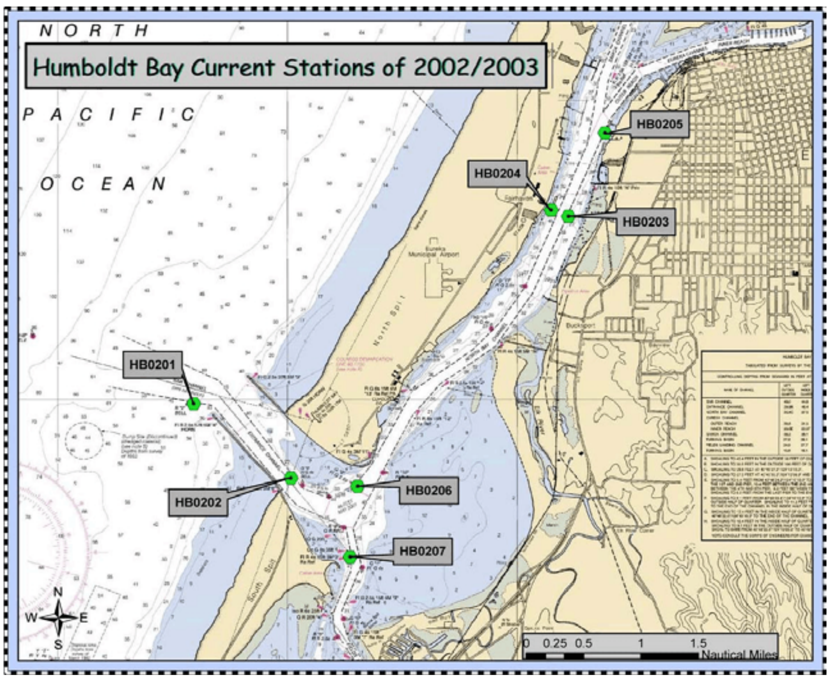

Figure 1. Humboldt Bay Current Survey Study Area of 2002/2003.

Bay at HB0202 was thwarted when high sediment transport buried the current meter platform and data acquisition was less than the required 30 days. Although the current direction measured at HB0202 did not align with the expected flow between the jetties in the Entrance Channel, the profiler did not malfunction. Current direction recorded at all levels throughout the water column were consistent with the direction of sediment transport and flow reflected off the north jetty and along the shoal just to the north of the profiler's position (Figure 2).

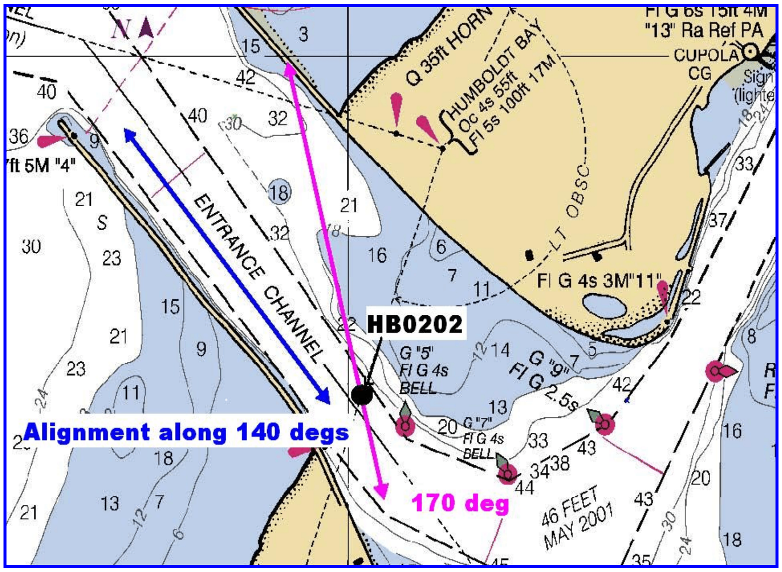

Figure 2. Questionable current alignment in the Entrance Channel

Another survey was conducted during the summer of 2004 to measure currents during a relatively quiescent meteorological period when wind and swells were expected to be less intense. Site selection, within the Entrance Channel, was determined from a 12-hour acoustic Doppler current

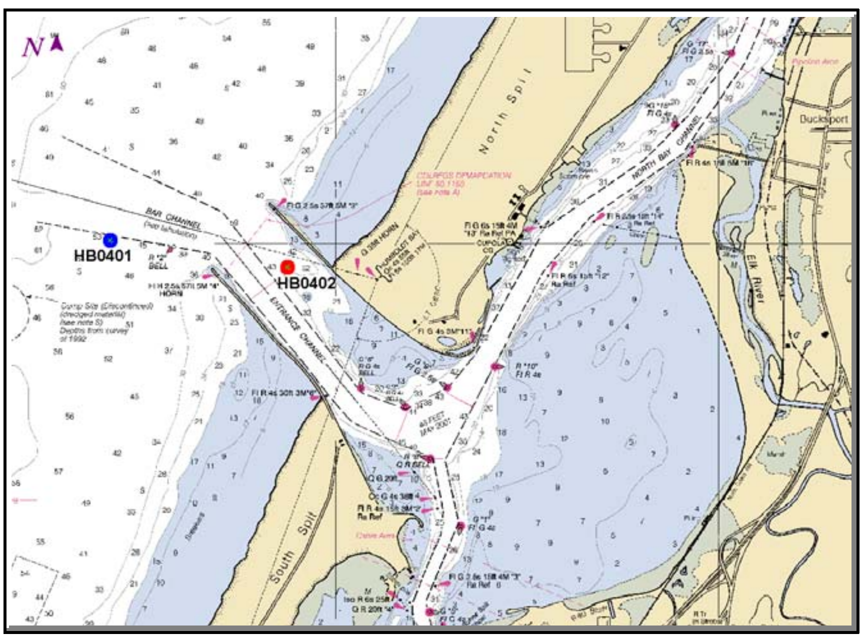

Figure 3. Humboldt Bay Current Survey Study Area of 2004

profiler (ADCP) tow where currents displayed the anticipated alignment with the main ship channel and sand movement was expected to be minimal. During this survey, two stations were occupied, one outside the harbor at HB0401 and one between the jetties at HB0402. Development of a new reference station at HB0402, 0.25nm SSE of the north jetty of the Entrance Channel (Figure 3), resulted when nearly 86 days of quality data were collected in 12.8 meters of water. Forty-nine days of data were collected outside the breakwater in 14.1 meters of water.

Upon completion of the summer project, data products were generated and new predictions are now available for all stations occupied during the 2002/2003 and 2004 surveys. New reference station daily predictions are available for the remainder of 2005 and will appear in the NOS Tidal Current Tables beginning with the 2006 edition. Due to the limited number of pages in the Tidal Current Tables, the Humboldt Bay stations are listed as secondary stations rather than stand-alone reference stations. All existing stations within Humboldt Bay will be referenced to the new Entrance Channel station. Time differences and speed ratios have been computed and will appear in Table 2 of the 2006 NOS Tidal Current Tables - Pacific Coast of North America and Asia. Raw and quality control (QC) data are available upon request. In addition, harmonic constituents and harmonic-based predictions are available upon request for all stations.

2.0 2002/2003 CURRENT SURVEY

An investigation was conducted by CO-OPS to address the Humboldt Bay Harbor District's (HBHD) concern that time differences from the predicted flood and ebb were experienced by the local marine community. As a result, a current survey to update predictions within the harbor and improve safe navigation began in December 2002. Normally CO-OPS conducts current surveys during 'normal' sea conditions to adequately measure the tidal currents in an area of concern to the maritime community. The users requested that this survey be conducted in the winter during the extreme conditions of storms and high sediment transport. Storms, *El Nino,* and hurricanes are not considered 'normal' sea conditions, therefore CO-OPS current surveys are not normally conducted during those times. Sometimes the passage of storms or other anomalies during a survey result in valuable oceanographic measurements.

2.1 Stations Occupied and Instrumentation Utilized

Seven locations were identified by the HBHD, the Humboldt Bay Bar Pilots, and CO-OPS as being critical to safe navigation. The seven stations spanned the breadth of the bay from just outside the breakwater at the entrance, north to Tosco Pier in North Bay Channel (Figure 1). Trawl resistant bottom mounted (TRBM) platforms designed and manufactured by Flotation Technologies were utilized at each of the four stations within the harbor at HB0202, HB0203, HB0206 and HB0207. (Refer to Table 1 for precise information on each station). The ADCP deployed in the Entrance Channel was housed in a concrete-based TRBM platform (Figure 4*e*) capable of withstanding

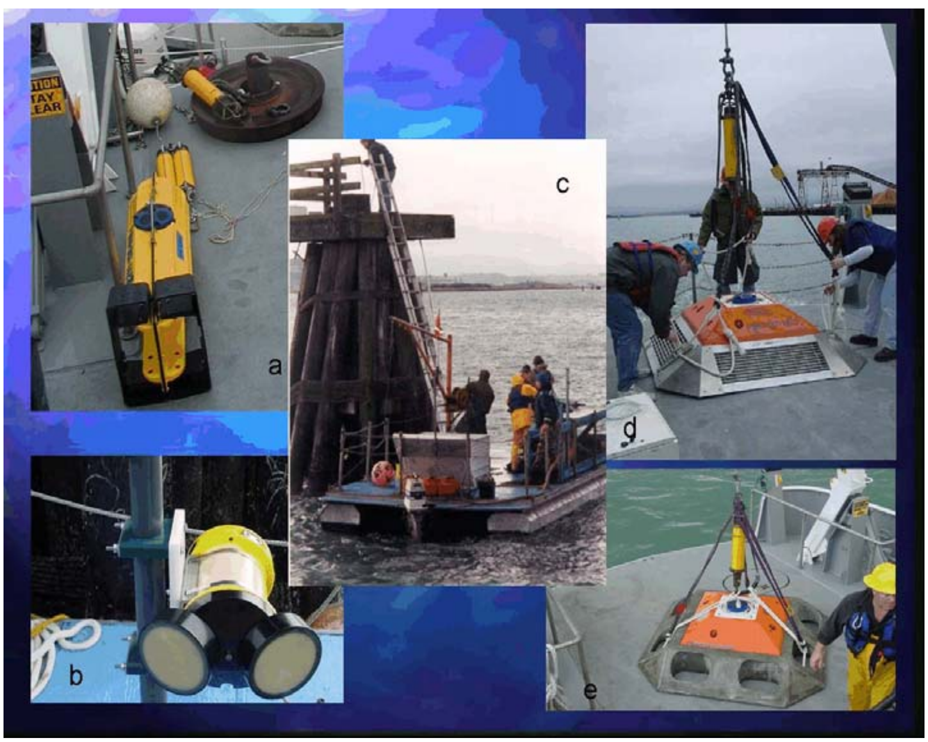

Figure 4. Equipment utilized during the 2002/2003 Humboldt Bay current survey consisted of (*a*) RDI WorkHorse ADCP in a subsurface buoy, (*b*) Sontek side looking profiler (SL-ADP), (*c*) mounted to the dolphin at Fairhaven Terminal, (*d*) bottom mounted ADCP housed in an aluminum base and (*e*) concrete base.

currents over 3 knots. The other three platforms had the standard aluminum base (Figure 4*d*). Two stations utilized side looking acoustic Doppler profilers (SL-ADP) mounted to the face of the pier at Tosco Pier and a stand-alone dolphin at Fairhaven Terminal (Figure 4*b* and 4*c*). One station deployed outside the jetties, utilized an ADCP housed in a subsurface buoy (Figure 4*a*).

Two separate deployments occurred during the winter survey; the first in December 2002 (*Entrance Channel and North Bay Channel*), and the second in late January 2003 (*Fields Landing Channel and North Bay Channel near channel marker #9 close to the US Coast Guard Station at Samoa, CA*). Table 1 provides station details of instruments utilized, deployment period, and days of quality data acquired.

Table 1. Station Summary for the 2002/2003 Humboldt Bay Current Survey

STATION			PROFILER		DEPLOYMENT PERIOD	GOOD QUALITY DATA
ID	Position	depth (m) below MLLW	s/n	Freq kHz		Days
HB0201	40^o 45.973' N 124^o 14.815' W	12.4	238	1200	12/09/02 - 03/01/03	5.68
subsurface buoy deployed ~8.5 meters east of ATON Bell Buoy 2, outside Bar Channel						
HB0202	40^o 45.475' N 124^o 13.967' W	14.2	2203	600	12/11/02 - 04/09/03	20.93
~25.5 meters northwest of ATON Bell Buoy 5, inside Entrance Channel						
HB0203	40^o 47.226' N 124^o 11.552' W	11.7	1062	1200	12/11/02 - 01/24/03	43.69
North Bay Channel opposite Fairhaven Terminal						
HB0204	40^o 47.266' N 124^o 11.700' W	4.6	C465	250	12/11/02 - 02/25/03	74.97
Fairhaven Terminal. Station depth is 10.8 meters. Multiple distances out to 201meters						
HB0205	40^o 47.771' N 124^o 11.237' W	4.6	C410	500	12/12/02 - 02/27/03	76.75
TOSCO Eureka Terminal Pier. Station depth is 9.1 meters. Multiple distances out to 161meters						
HB0206	40^o 45.465' N 124^o 13.367' W	14.3	3096	600	01/24/03 - 02/28/03	34.3
near marker #9, inside Entrance Channel on north side at the confluence with North Bay Channel						
HB0207	40^o 44.871' N 124^o 13.446' W	8.9	1062	1200	01/24/03 - 2/27/03	33.9
near marker #2, at the entrance to Fields Landing Channel						

NOTE: Sensor depth is given at stations, HB0204 and HB0205 instead of station depth.

Deployment of the SL-ADP at the Tosco pier and on the stand-alone dolphin at Fairhaven Terminal utilized the HBHD pontoon boat, while the heavier bottom mounted platforms were deployed with the Humboldt State University's *RV Coral Sea*.

2.2 Data Acquired and Results

One of the challenges associated with this survey was the extreme sediment transport through the Entrance Channel complicated by longshore currents that mix with jetty-produced eddies outside the harbor. Site selection was determined by talking to numerous local marine experts, all of whom helped to identify areas where current predictions were inadequate. CO-OPS mission to promote safe navigation and update tidal current predictions played a key role in selecting the sites within the harbor.

Normally, subsurface buoys are deployed at depths in excess of 30.5 meters and in areas where sediment loading is high [NOAA, 2003]. The depth near ATON Bell Buoy #2 was about 14 meters and migrating sand movement was known to occur in the vicinity of the mooring. Performance of the subsurface buoy was compromised by the short mooring chain, shallow station depth, and excessive tilts. The mooring broke from its chain early in the deployment and only 5.7 days of quality data were recovered from the subsurface buoy after it was found and returned to CO-OPS in May 2003, almost 5 months after it was deployed. Figure 5 shows that both pitch and roll were approaching excessive levels (greater than 20 degrees). The data showed that north velocity was in excess of 4.5 knots at 7.9 meters below mean lower low water (MLLW). CO-OPS present suite of instrumentation had known limitations in high surge conditions which are prevalent in this area of the Bay especially during an *El Nino* year. After the subsurface buoy broke from its mooring, it was carried north along the coast until it beached on the coast near McKinleyville, CA.

Side looking profilers were utilized in Humboldt Bay to characterize the currents in the North Bay Channel. CO-OPS has successfully acquired quality data with horizontal current meters in areas near berthing and piers where a bottom mounted system could be compromised by deep draft vessels offloading their products [Earwaker, 2002]. Figure 6 shows the principal current direction from the

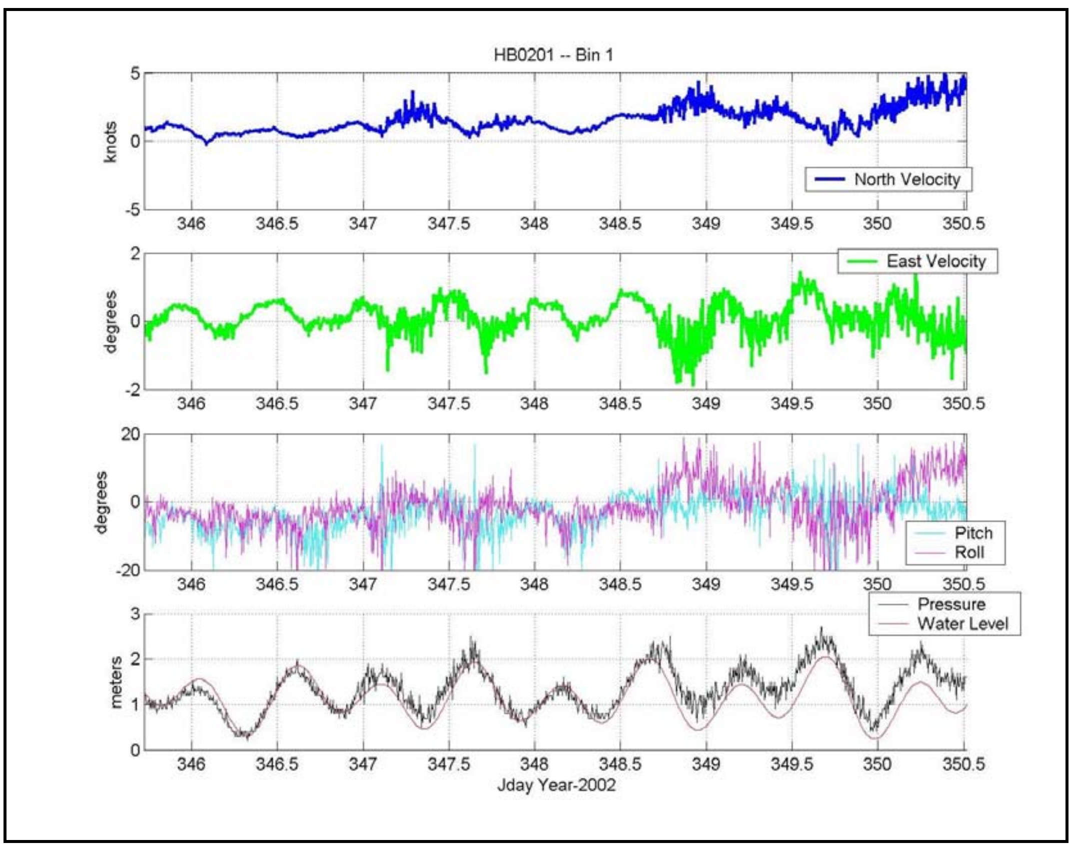

Figure 5. Current velocity and tilts of HB0201 data at 7.9 m.

western side of North Bay Channel at HB0204 (Bin 1) to the eastern side at HB0205 (Figure 7). The Fairhaven Terminal SL-ADP, deployed at a depth of 15 feet, measured currents that were aligned with the main ship channel for the entire profiling range of 200 meters (Figure 6). The profiler at Tosco Pier also measured currents from the eastern side of the channel to a distance of 161 meters; it also showed alignment with the North Bay Channel flow (Figure 7). Figure 7 shows about a 15 to 20 degree shift in direction between the farthest and nearest range, although all measurements align with the main ship channel.

Installation of the mounting hardware was accomplished by divers in 10.79 meters of water with the sensor mounted at 4.5 meters below MLLW. Only one 250 kHz H-ADCP was available for this survey and the sensor was deployed at Fairhaven Terminal. Maximum profiling range of the SL-ADPs were attained owing to adequate scatterers and their placement in the water column.

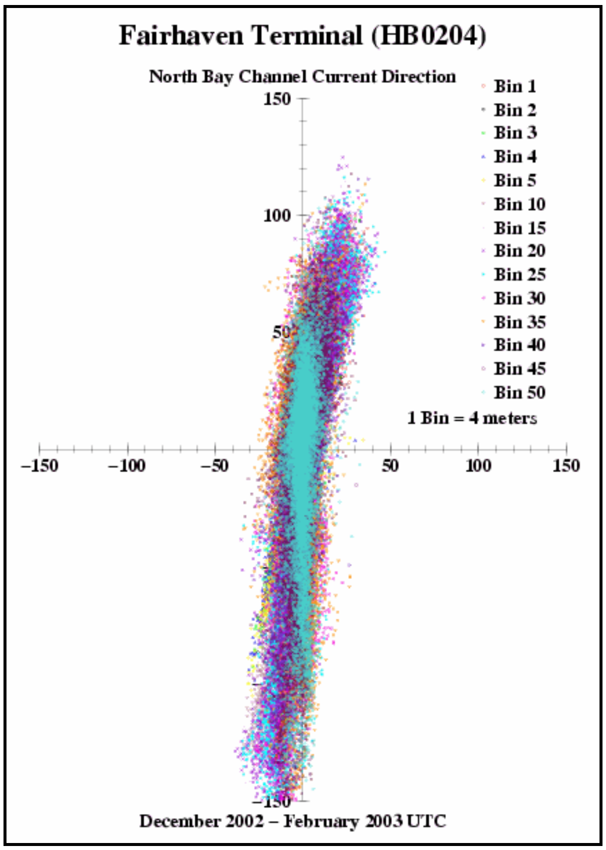

Figure 6. Velocity scatter diagram for Fairhaven Terminal (HB0204) showing bins 1 through 50 (~ 200 meters from the dolphin).

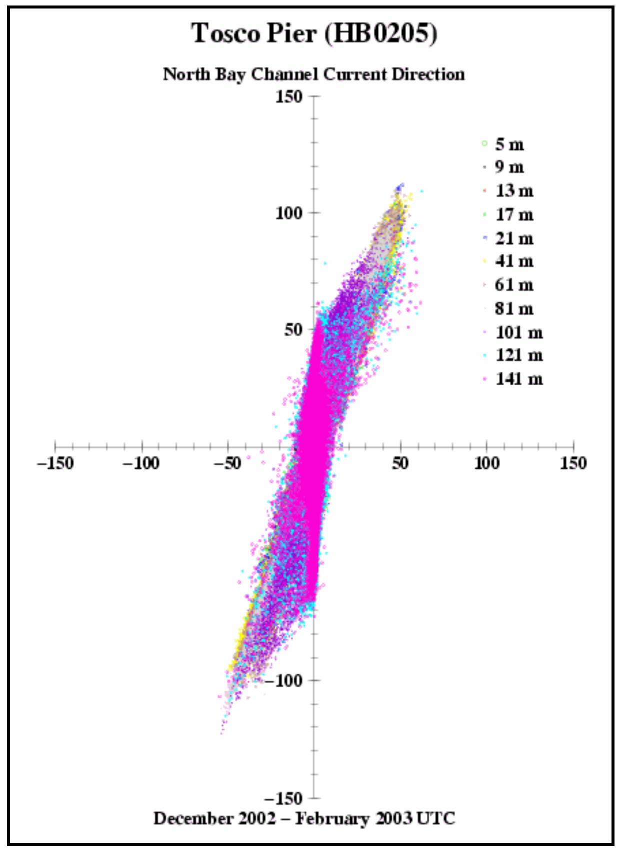

Figure 7. Velocity scatter diagram for Tosco Pier (HB0205) from 5 meters through 141 meters from the pier.

Examples of range in 2002 are shown in Figure 8 at Tosco Pier and Figure 9 at Fairhaven Terminal. The low signal to noise (SNR) threshold at 7 counts is the cutoff for quality data. The largest echo intensities are closest to the profiler at bin 1 at a range of 5 meters and become progressively less as the distance increases out to Bin 40 at 161 meters (Figure 8). Echo intensities from the 250 kHz Sontek SL-ADP at Fairhaven Terminal exceeded maximum profiling range (120 to 180 meters) in

December 2002 without coming close to the SNR threshold (or cutoff). Measured echo intensities during 2003 were occasionally below the SNR threshold.

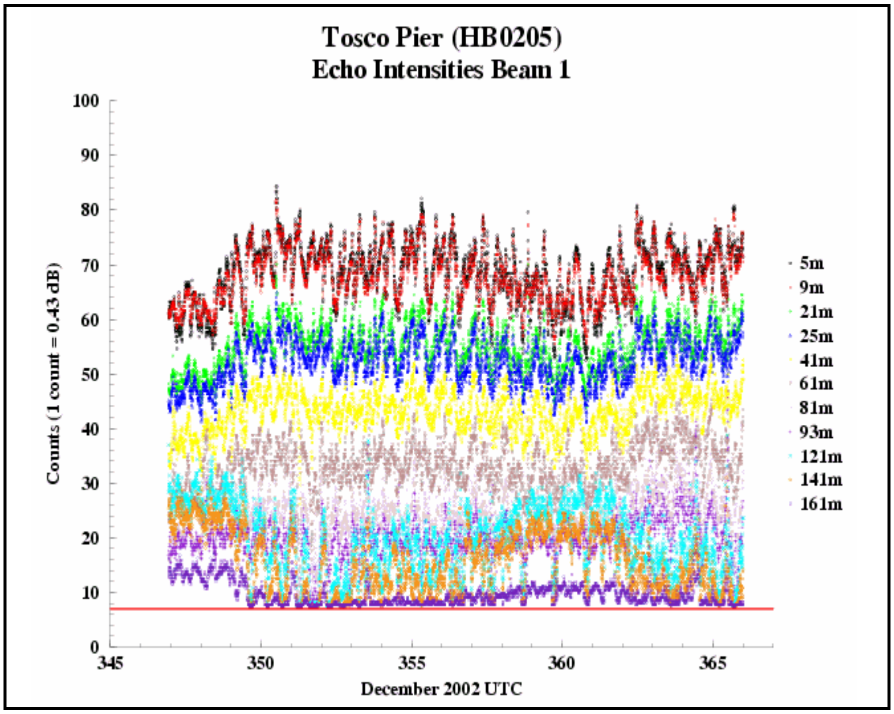

Figure 8. Echo intensity range of beam 1 from Tosco Pier SL-ADP during the 2002 deployment. Low signal to noise threshold is at 7 counts (solid red line).

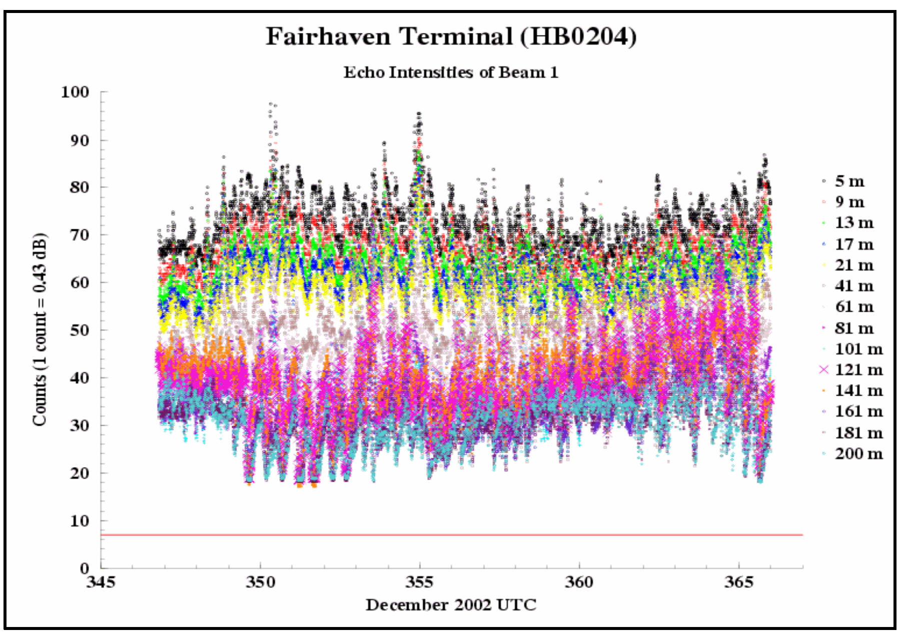

Figure 9. Echo intensity range of beam 1 from Fairhaven Terminal SL-ADP during the 2002 deployment. Solid red line is low signal to noise threshold at 7 counts.

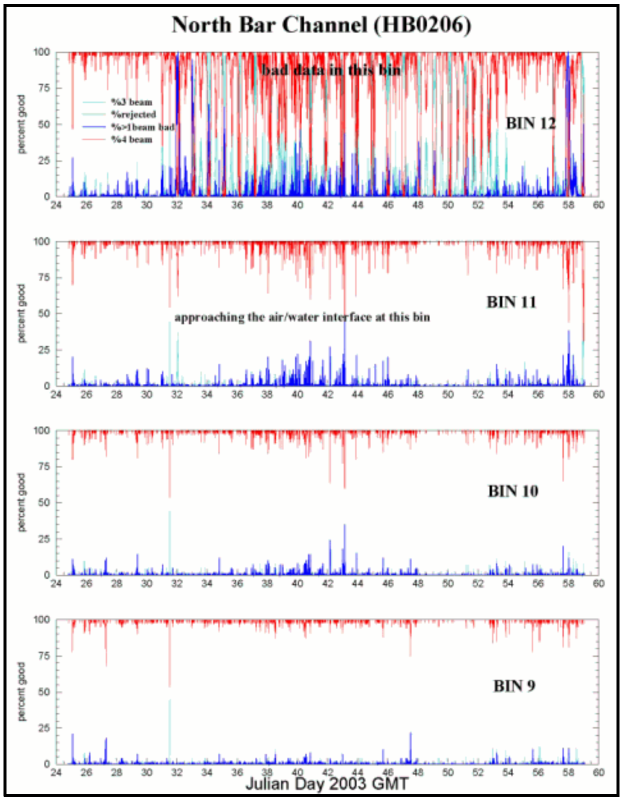

Figure 10. Percent good pings as an indicator of range at HB0206. Bin 12 at 2 feet (below MLLW) is at the air/water interface.

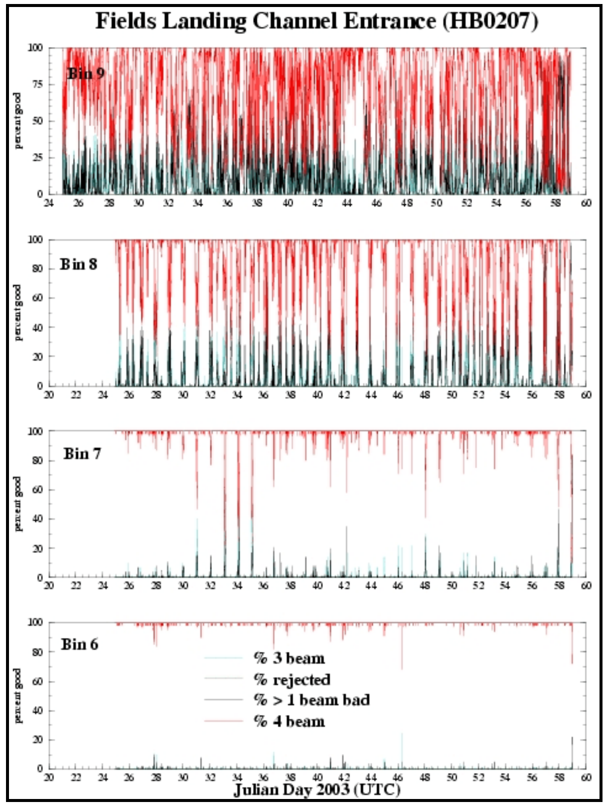

Figure 11. Percent good pings as an indicator of range at HB0207. Bin 7 at 2.3 feet (below MLLW) is the last good bin (near the surface).

Data quality (as percent good pings) at two stations (HB0206 and HB0207) are shown in Figures 10 and 11, respectively. Last good bin range is the depth where "percent 4 beam solution" is very close to 100% (greater than 75%). Last good bin at HB0206 (Figure 10) is Bin 11 at 1.6 m below MLLW. Last good bin at HB0207 (Figure 11) is Bin 7 at 0.7 m below MLLW.

Principal current direction changes from top to bottom during the deployment at station HB0206 (Figure 12), where the surface depth is represented by green and the bottom depth by black/red symbols. The current mostly aligns with the main ship channel with higher speeds toward the entrance of Humboldt Bay. The flood direction is almost due east near channel marker #9 (station HB0206) where Figure 12 shows flood currents are deflected off the south jetty and flow toward North Bay Channel. The principal current direction, at station HB0207 during the January to February deployment, shows good alignment along the north/south orientation of Fields Landing Channel (Figure 13). This station also had higher speeds toward the entrance of Humboldt Bay at all depths (Figure 13). The principal flood direction is southeast near channel marker #2, (station HB0207) as expected in a narrow channel opening such as at the entrance to Fields Landing Channel.

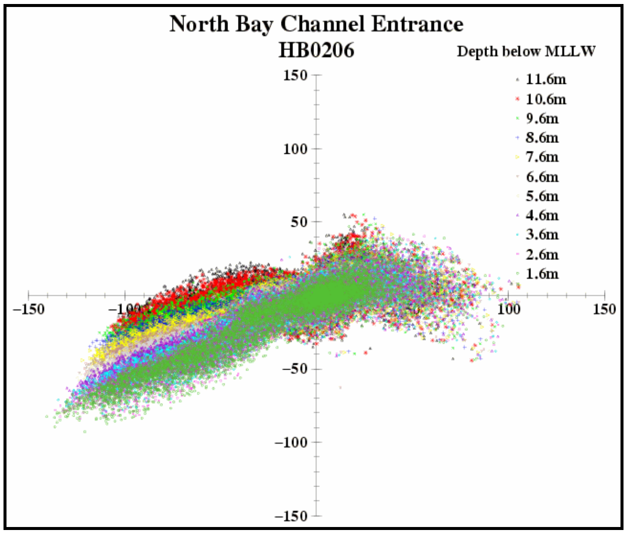

Figure 12. Principal current direction (January-February, 2003) at multiple depths at station HB0206.

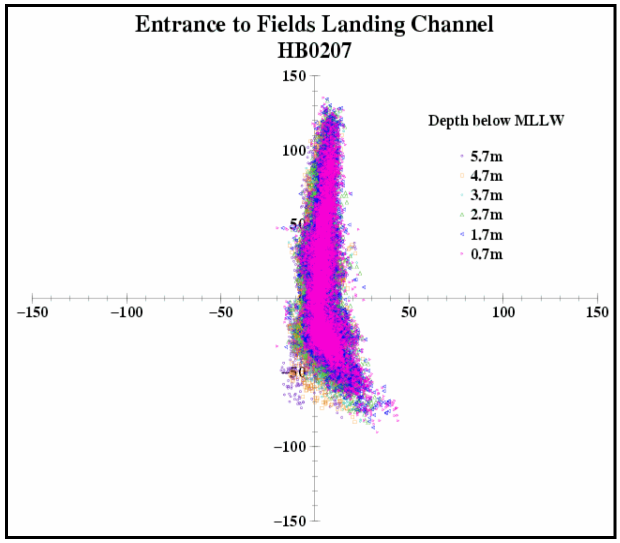

Figure 13. Principal current direction (January - February, 2003) at multiple depths at station HB0207.

2.3 Products Available

Loss of data from the proposed reference station posed a challenge to CO-OPS since a full update to the Humboldt Bay predictions was not possible. As an interim measure, CO-OPS published special 2004 "Daily Predictions" for the five stations, but left them referenced to the existing station at San Francisco Bay Entrance. The entrance station of Humboldt Bay was re-occupied during the summer survey to acquire at least 30 days of data to perform harmonic analysis and develop a new reference station for Humboldt Bay.

Special 2004 "Daily Predictions" for five of the seven stations occupied were made available to the Humboldt Bay Harbor Safety Committee at their September 2003 meeting. Other copies were distributed to individuals who expressed an interest. Table 2 time differences and speed ratios as referenced to San Francisco Bay Entrance were also generated and were disseminated in the 2005 edition of the Tidal Current Tables released in January 2005. Results of Greenwich interval analysis, showing hours of each phase of the tidal current versus depth, are shown in Figures 14-19. Greenwich intervals are the periods between the moon's transit over the Greenwich meridian and the arrival of each tidal phase at a station [Zervas, 2000]. Generally, multiple depths from a single station will have Greenwich intervals close to the adjacent depth as shown in Figures 14, 15, 18 and 19.

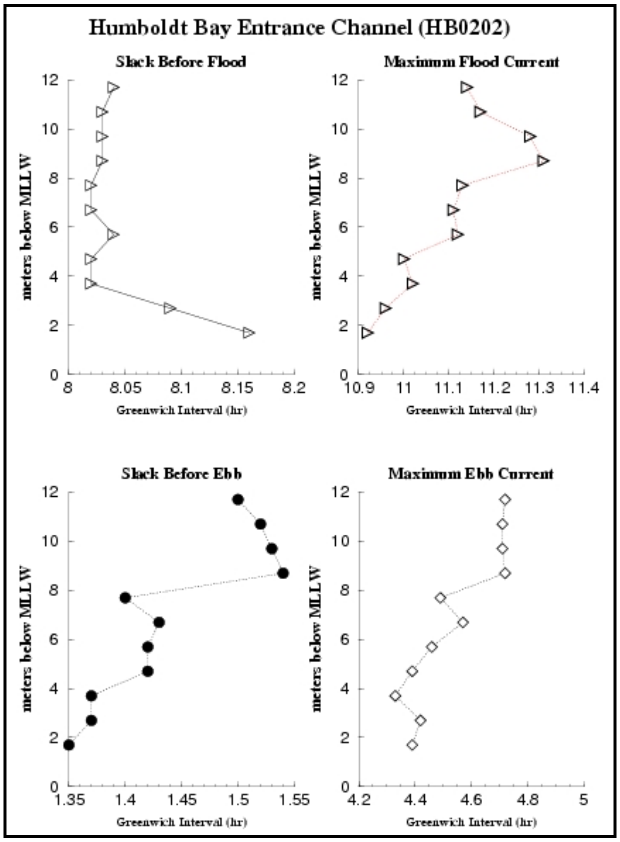

Figure 14. Greenwich intervals (hours) with depth at Humboldt Bay Entrance Channel station, HB0202. Station depth is 14.2m.

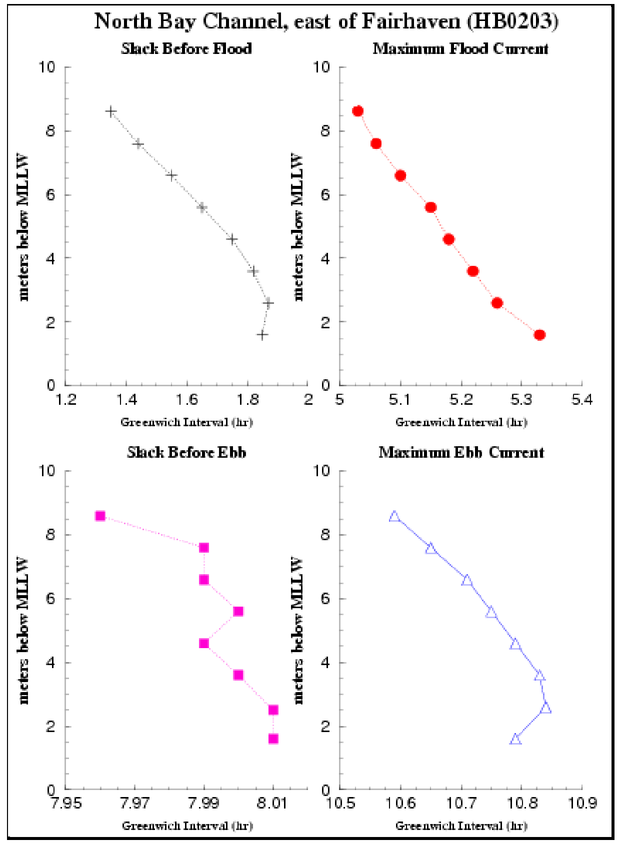

Figure 15. Greenwich intervals (hours) withdepth at North Bay Channel station, HB0203 east of Fairhaven. Station depth is 11.7m.

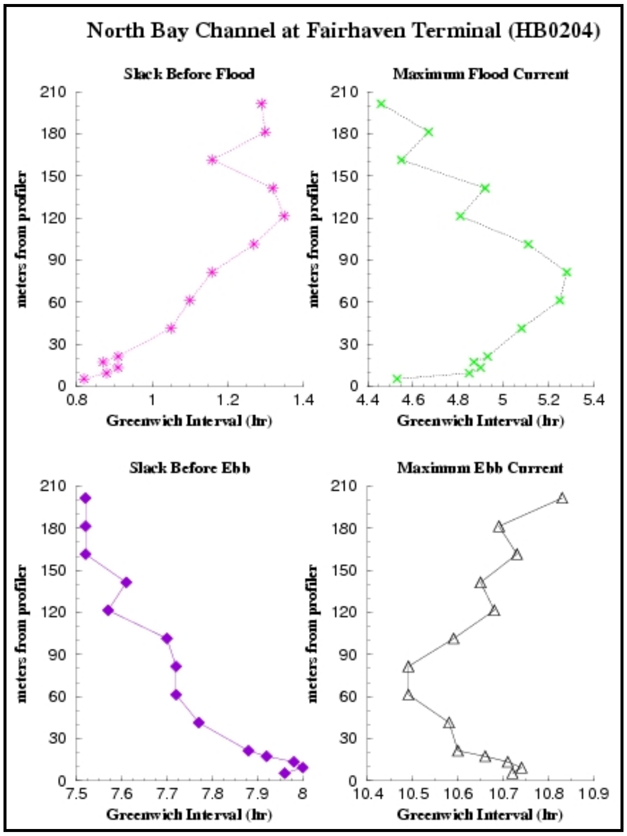

Figure 16. Greenwich intervals (hours) with distance from Fairhaven Terminal station, HB0204. Western edge of North Bay Channel is at 41m and middle of the channel is near 200m.

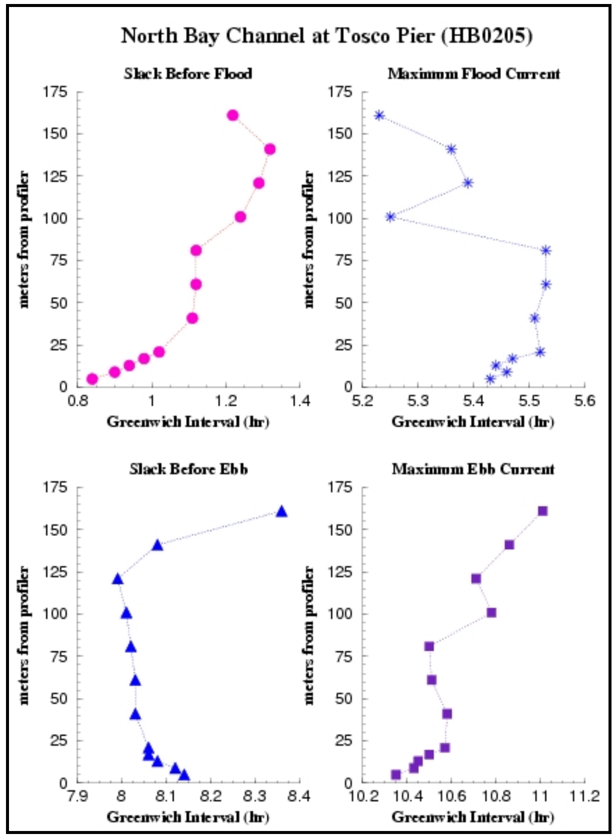

Figure 17. Greenwich intervals (hours) withdistance from Tosco Pier station, HB0205. Eastern edge of North Bay Channel is at 25m.

Figures 16 and 17 show results from the horizontal profiler where distances are from the mount out toward the main ship channel, rather than vertical depth measured in meters below MLLW. Note that timing of the maximum flood current at station HB0204 (Figure 16, 200m) should occur before the maximum flood at HB0205 (Figure 17, 161m). One would expect the Greenwich intervals from station HB0203 (Figure 15, 4.5m) to be quite close in time to the 200 meter distance at station HB0204 (Figure 16) since they are measuring nearly the same water. However, this is not the case. It appears that the timing of maximum flood current at HB0203 occurs about 50 minutes after the maximum flood current at HB0204. This means that the profilers are not measuring the same volume of water and the west side of the channel floods faster than the east side. The horizontal profiler samples nearly the entire water column at locations farthest from the sensor so some errors may be introduced from side lobe interference that could contribute to the difference in Greenwich interval hours between the two stations.

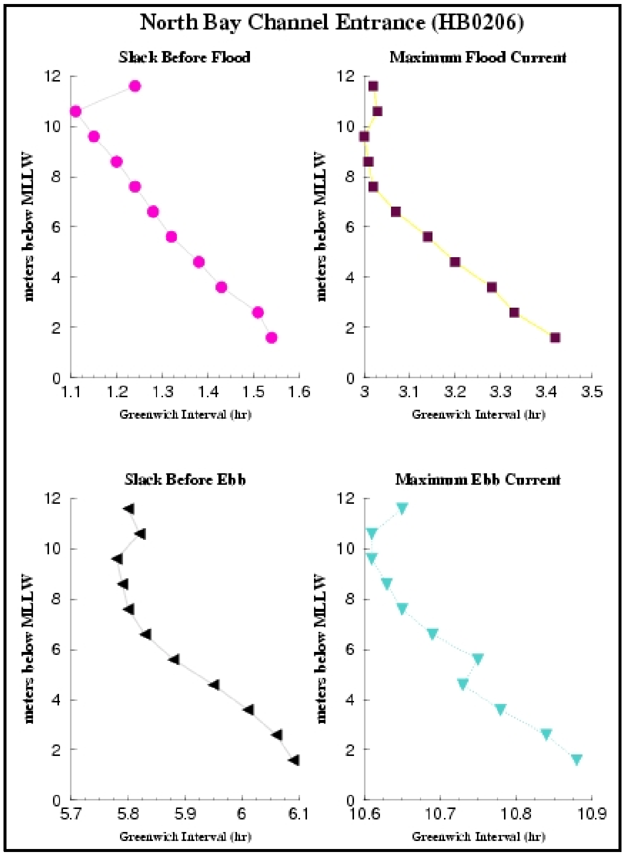

Figure 18. Greenwich intervals (hours) with depth at North Bay Channel station, HB0206. Station depth is 14.3m.

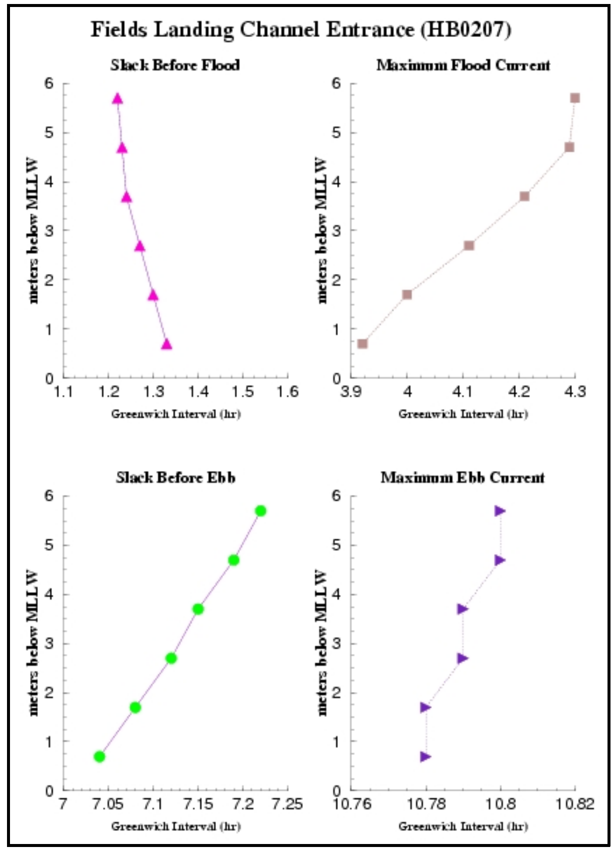

Figure 19. Greenwich intervals (hours) with depth at Fields Landing Channel station, HB0207. Station depth is 8.9m.

Speed ratios and time differences for the Humboldt Bay stations that appeared in Table 2 of the 2005 NOS Tidal Current Tables are presented in Table 2 below.

Table 2. Table 2 of speed ratios and time differences for Humboldt Bay stations referenced to San Francisco Bay Entrance from the 2005 NOS Tidal Current Tables - Pacific Coast of North America and Asia.

TABLE 2 – CURRENT DIFFERENCES AND OTHER CONSTANTS (2005)

No.	PLACE	Meter Depth	POSITION		TIME DIFFERENCES				SPEED RATIOS		AVERAGE SPEEDS AND DIRECTIONS							
			Latitude	Longitude	Min. before Flood	Flood	Min. before Ebb	Ebb	Flood	Ebb	Minimum before Flood		Maximum Flood		Minimum before Ebb		Maximum Ebb	
		ft	North	West	h m	h m	h m	h m			knots	Dir.	knots	Dir.	knots	Dir.	knots	Dir.
	CALIFORNIA COAST Time meridian, 120° W				on San Francisco Bay Ent., p.8													
946	Point Reyes <13>		38°00'	123°02'	–1 12	–1 12	–1 12	–1 12	0.3	0.3	– –	– –	1.1	320°	– –	– –	1.1	140°
951	Salt Point <13>		38°34'	123°21'	–1 20	–1 20	–1 20	–1 20	0.3	0.3	– –	– –	0.9	325°	– –	– –	0.9	145°
956	Point Arena <13>		38°57'	123°45'	–1 29	–1 29	–1 29	–1 29	0.3	0.3	– –	– –	1.1	330°	– –	– –	1.1	150°
961	Point Cabrillo <13>		39°21'	123°50'	–1 38	–1 38	–1 38	–1 38	0.3	0.3	– –	– –	1.0	345°	– –	– –	1.0	165°
966	Cape Vizcaino <13>		39°44'	123°50'	–1 48	–1 48	–1 48	–1 48	0.3	0.3	– –	– –	0.9	325°	– –	– –	0.9	145°
971	Point Delgada <13>		40°00'	124°04'	–1 37	–1 37	–1 37	–1 37	0.3	0.3	– –	– –	1.0	325°	– –	– –	1.0	145°
976	Punta Gorda <13>		40°15'	124°22'	–1 36	–1 36	–1 36	–1 36	0.3	0.3	– –	– –	1.1	335°	– –	– –	1.1	155°
981	Cape Mendocino Light, 4.6 mi. W of <14>		40°26'	124°30'	– – –	– – –	– – –	– – –	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
986	Table Bluff Light <13>		40°42'	124°17'	–1 11	–1 11	–1 11	–1 11	0.3	0.3	– –	– –	0.8	010°	– –	– –	0.8	190°
	HUMBOLDT BAY																	
991	Humboldt Bay entrance		40°45.48'	124°13.80'	–0 52	–0 51	–1 09	–0 44	0.6	0.6	– –	– –	1.6	124°	– –	– –	2.0	312°
996	North Spit, 0.15 n.mi. SW of	15d	40°45.47'	124°13.37'	–1 44	–2 40	–3 18	–1 18	0.2	0.5	0.1	155°	0.6	073°	– –	– –	1.6	243°
	...do.	32d	40°45.47'	124°13.37'	–1 58	–2 52	–3 28	–1 25	0.2	0.4	– –	– –	0.5	070°	– –	– –	1.3	257°
1001	South Spit, 0.1 n.mi. NE of	15d	40°44.87'	124°13.45'	–1 53	–1 35	–2 04	–1 14	0.3	0.4	– –	– –	0.8	178°	0.1	086°	1.2	002°
1006	North Bay Channel, west of Eureka	15d	40°47.23'	124°11.56'	–1 23	–0 42	–1 17	–1 13	0.5	0.5	– –	– –	1.6	021°	– –	– –	1.8	197°
	...do.	28d	40°47.23'	124°11.56'	–1 47	–0 53	–1 19	–1 24	0.5	0.4	– –	– –	1.4	013°	0.1	286°	1.4	200°
1011	North Bay Channel at Fairhaven	13d	40°47.24'	124°11.66'	–1 45	–0 38	–1 28	–1 27	0.5	0.5	– –	– –	1.3	030°	– –	– –	1.8	216°
1016	North Bay Channel at Samoa Channel	15d	40°47.77'	124°11.24'	–1 49	–0 35	–1 17	–1 29	0.4	0.4	– –	– –	1.2	015°	– –	– –	1.3	196°
	CALIFORNIA COAST–cont.																	
1021	Trinidad Head <13>		41°03'	124°10'	–0 57	–0 57	–0 57	–0 57	0.3	0.3	– –	– –	1.0	005°	– –	– –	1.0	185°
1026	Redding Rock Light <13>		41°21'	124°11'	–0 52	–0 52	–0 52	–0 52	0.3	0.3	– –	– –	0.9	010°	– –	– –	0.9	190°
1031	St. George Reef <13>		41°49'	124°20'	–0 41	–0 41	–0 41	–0 41	0.3	0.3	– –	– –	1.0	005°	– –	– –	1.0	185°

Endnotes can be found at the end of table 2.

CO-OPS is developing web-based access to the data.

3.0 2004 CURRENT SURVEY

CO-OPS was unable to compute tidal current predictions in the Entrance Channel and outside the harbor during the 2002/2003 survey due to the series of storms that hit the coast of northern California in December and January. There was a failure to acquire at least 30 days of data because of the loss of the subsurface ADCP at HB0201 and burial of the bottom platform at HB0202. Because of this, a second attempt to acquire data at the entrance to the harbor (utilizing a subsurface buoy and open type bottom platform) was performed in July 2004. Cross sectional current measurements at the entrance area (utilizing a vessel mounted ADCP system) (Figure 20*a*) helped

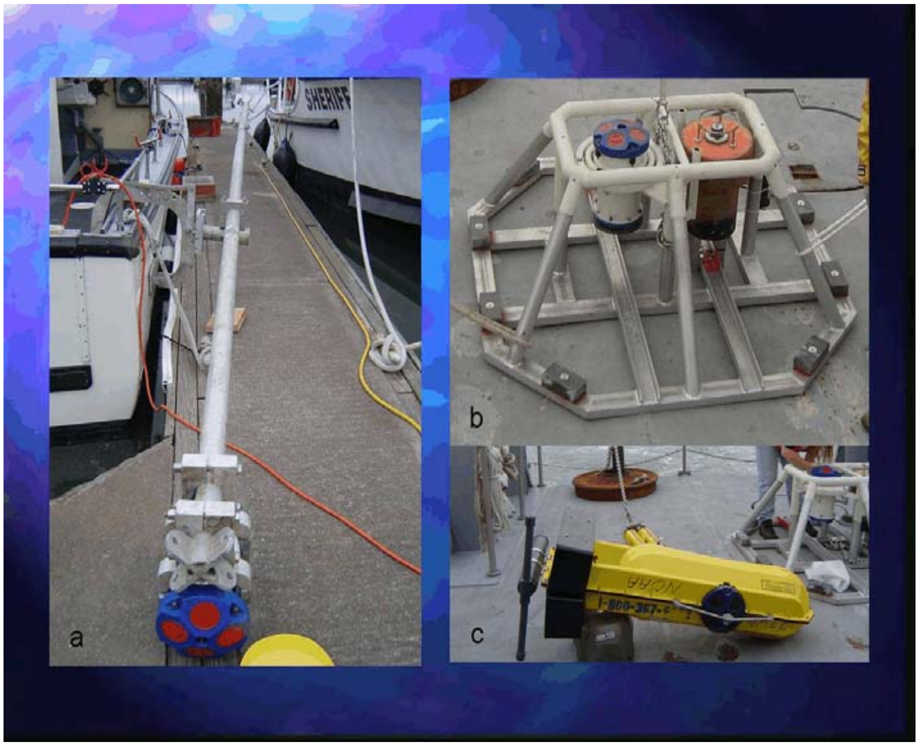

Figure 20. Equipment utilized during the 2004 Humboldt Bay current survey consisted of: (*a*) vessel mounted ADCP attached to a 15 foot pole, (*b*) bottom mounted ADCP, and (*c*) subsurface buoy with Argos beacon and dual acoustic releases.

to identify an area where currents were representative of the main ship channel. CO-OPS was concerned about sediment transport through the harbor and potential burial of the bottom platform, but several sources assured the team that the north side of the main ship channel was less likely to develop sand shoals or be affected by migration of sand through the harbor during the summer. Breakers appeared to come in straight through the jetties and weren't deflected from the north jetty as observed during the winter season of 2002. The station outside of the harbor (HB0401) was positioned in deeper water and farther away from the previous site deployed at the ATON Bell Buoy 2, thus assuring it wouldn't be clipped by any passing deep draft vessels transiting the entrance or within the watch circle of the ATON Bell Buoy 2 buoy.

3.1 Stations Occupied and Instrumentation Utilized

The station outside the breakwater (HB0401) utilized a 1200 kHz RD Instruments WorkHorse ADCP housed in a subsurface buoy, with a 3.5 meter long mooring line, attached to a railroad wheel anchor (Figure 20*c*). The subsurface buoy, equipped with an ARGOS beacon, was deployed in 14 meters of water about 0.4 nautical miles west northwest of the south jetty, on the edge of the Bar Channel. The current profiler measured currents every six minutes (from near bottom (9.3 meters) to the surface) from July 21 to September 8, 2004.

The station inside the jetties (HB0402) housed an ADCP inside an open-sided bottom platform (Figure 20*b*) where currents less than 3 knots were expected. A 1200 kHz RD Instruments ADCP was configured to sample and record currents, tilts, heading, pressure, and water temperature every six minutes. The profiler was deployed in 12.7 meters of water near the north jetty rock marker (labeled “58") from July 21 to October 15, 2004.

Some complications were encountered at the Entrance Channel station when the pop-up release (float) attached to the platform was cut on September 17. All physical reference to the location of the bottom platform was lost at that time. Divers, using the last known GPS fix of the platform from the deployment log, searched for the platform and profiler on three separate occasions. The profiler was finally recovered by the divers on October 14 after NOAA’s Navigation Response Team #6 pinpointed its location with their side scan sonar. The platform was buried under about 2 feet of sand and was left at the site after attempts to release it using a hydraulic pump were unsuccessful. The body of the ADCP was completely encrusted with growth and marine fouling although this did not affect data quality.

3.2 Data Acquired and Results

Nearly forty-nine days of quality data from the station outside the breakwater and about 86 days of data from the Entrance Channel site were acquired during the summer survey. Data and station information are summarized in Table 3. Data from the 4.5 meter depth at station HB0402 in the Entrance Channel will be used as a new reference station for all Humboldt Bay stations, including additional depths at HB0402 and 2 depths at HB0401.

Table 3. Station Summary for the 2004 Humboldt Bay Current Survey

STATION			PROFILER		DEPLOYMENT PERIOD	GOOD QUALITY DATA
ID	Position	depth	s/n	Freq		Days
		(m) MLLW		kHz		
HB0401	40° 46.013' N 124° 15.179' W	14.1	238	1200	07/21/04 - 09/08/04	48.86
subs buoy; 0.4 nm WNW of south jetty outside Bar Channel						
HB0402	40° 45.906' N 124° 14.252' W	12.7	604	1200	07/21/04 - 10/15/04	85.9
0.25nm SSE of north jetty in the Entrance Channel						

HB0401

Although beam 2 at HB0401 was degraded (Figure 21) and the ADCP returned to RDI for repair, the data are considered good for analysis as shown in the percent good ping plot of Bin 1(Figure 22). Analysis using 3 beam solution was performed on all ten of the 1-meter bins.

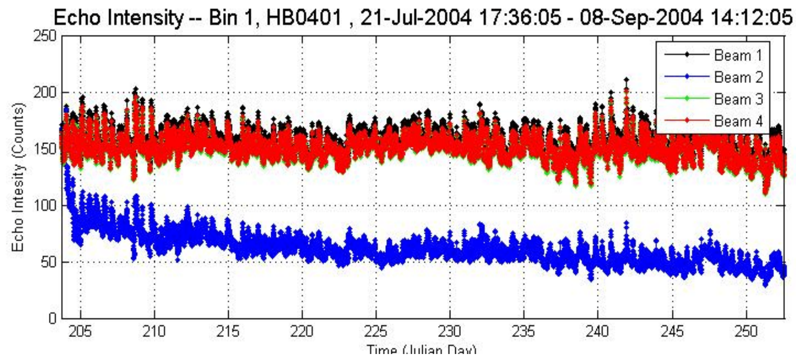

Figure 21. Time series of echo intensity at 9.3 m (MLLW) showing instant degradation of beam 2 of the ADCP deployed outside the Bar Channel.

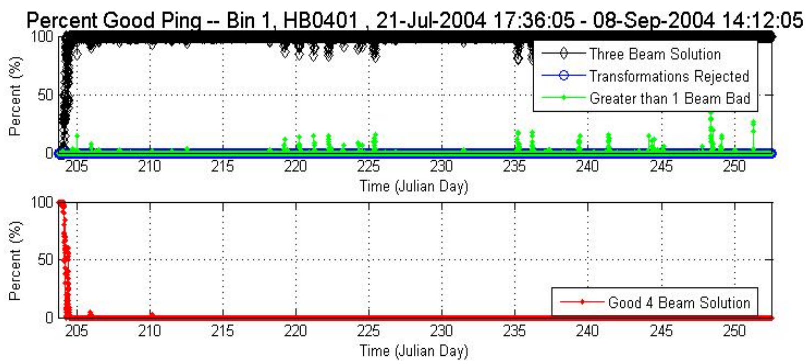

Figure 22. Percent good pings of HB0401 data at 9.3 m below MLLW.

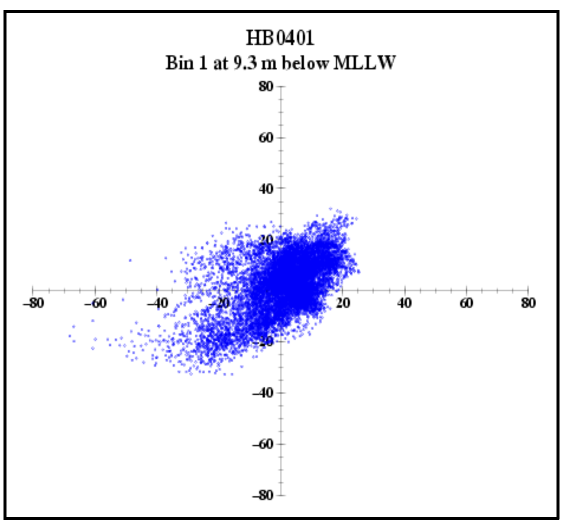

Figure 23. Principal current direction near the bottom at subsurface buoy station, HB0401.

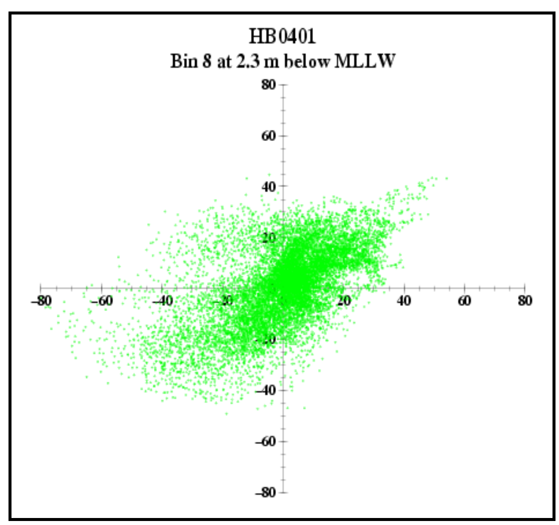

Figure 24. Principal current direction near the surface at subsurface buoy station, HB0401.

Principal current direction at two depths (near surface and near bottom) from station HB0401 are shown in Figures 23 and 24. The tidal signal is weak, currents are dominated by alongshore drift.

HB0402

Speed histograms (at the new reference station, HB0402) are shown in Figures 25-26. Flood current direction is about 142 degrees true North. As expected, the flood currents are stronger than the ebb currents near the bottom (Figure 25). Near-surface currents show about the same strength for flood and ebb (Figure 26).

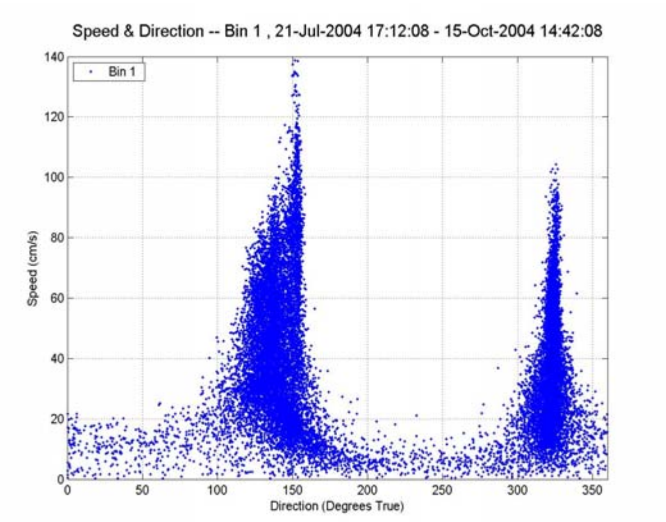

Figure 25. Principal current direction near the bottom at station, HB0402.

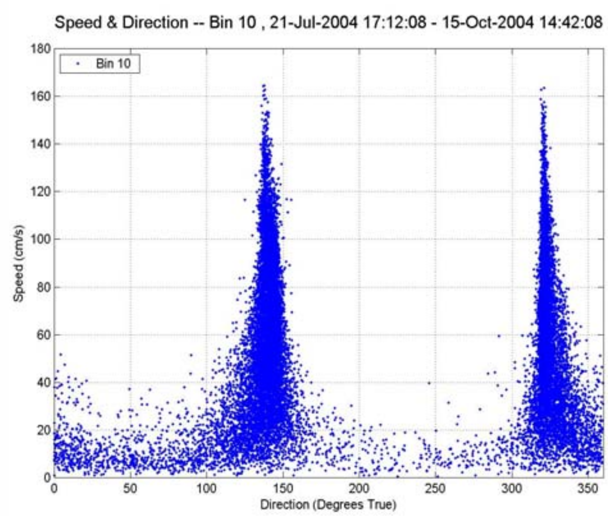

Figure 26. Principal current direction near the surface at station HB0402.

Mean flood current is slightly stronger than mean ebb at all depths at HB0402. Mean ebb current is stronger than mean flood at HB0202, HB0206, and HB0207 (all depths) which agrees with the permanent current directions (Table 3). These differences may be due to location of the good quality measurement and not seasonal influences. Principal current direction aligns with the Entrance Channel along 140 degrees true North at all depths below MLLW from 10.5 meters to 1.5 meters (surface) at HB0402 (Figure 27). The reference station, at depth 4.5 meters below MLLW, is shown as the gray filled triangle in Figure 27 and is highlighted in bold font in Table 4.

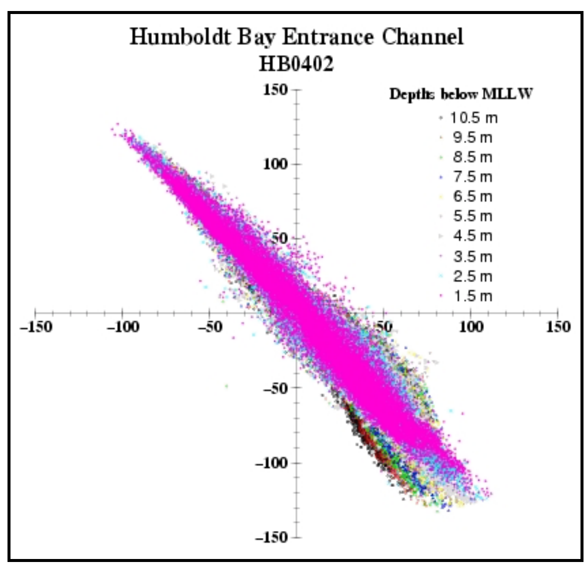

Figure 27. Principal current direction at multiple depths at the new Humboldt Bay reference station, HB0402.

Table 4. Characteristics of observed currents at selected depths below MLLW within the Entrance Channel: 2002-2004

STATION			Mean MFC		MAX MFC		Mean MEC		MAX MEC		Permanent Current		Principal Current
ID	Location / Description	Depth	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Spd	Dir	Direction
		(m)	kt	° T	kt	° T	kt	° T	kt	° T	kt	° T	° T
HB0402	40° 45.906'N 124° 14.252'W	10.5	1.31	141	2.65	152	1.06	323	2.02	326	0.171	136	143
		4.5	**1.74**	**140**	**3.20**	**140**	**1.59**	**322**	**2.95**	**322**	**0.148**	**129**	**142**
		1.5	1.64	140	3.22	137	1.53	323	3.3	322	0.093	123	142
0.25nm SSE of north jetty in the Entrance Channel													
HB0202	40° 45.475'N 124° 13.967'W	12.2	1.25	172	2.13	169	1.77	347	3.0	338	0.257	344	169
		9.2	1.5	171	2.23	175	2.06	346	3.3	339	0.271	343	168
		4.2	1.61	168	2.76	176	2.19	341	3.48	343	0.287	336	165
		1.2	1.46	168	2.45	175	2.06	340	3.59	344	0.337	338	164
25.5 meters NW of ATON Bell Buoy #5, inside Entrance Channel													
HB0206	40° 45.465'N 124° 13.367'W	9.6	0.60	070	2.02	086	1.27	257	2.25	250	0.331	258	077
		4.6	0.63	073	1.85	116	1.63	243	2.81	244	0.483	239	065
		1.6	0.65	071	1.58	081	1.88	237	3.17	239	0.537	233	060
entrance to North Bay Channel & inside Entrance Channel near channel marker #9													
HB0207	40° 44.871'N 124° 13.446'W	5.7	0.78	181	1.56	170	1.16	001	2.33	004	0.138	004	001
		4.7	0.80	178	1.62	166	1.24	002	2.42	004	0.16	013	001
		1.7	0.78	169	1.71	160	1.41	004	2.61	004	0.241	024	178
entrance to Fields Landing Channel near channel marker #2													

NOTES: MAX MFC & MAX MEC refers to the maximum observed current during the deployment.

The new reference station at HB0402 at 4.5 meters below MLLW is highlighted in bold font.

Data quality of the new reference station at HB0402 shows good "percent 4-beam solution" up to the surface at Bin 10 (Figure 28). Some of the deployment showed very low "percent 4-beam solutions", which may be the result of times when the platform and sensor were affected by migrating sand shoals.

Tidal Current Predictions

Comparison of predictions for the new reference station versus the existing reference station at the Entrance to San Francisco Bay show that the Humboldt Bay Entrance Channel station (HB0402) matches observations at two stations within the harbor better than the old reference station. Figures 29-32 show the comparisons during both a neap and spring tide at stations HB0206 and HB0205. The predictions are expected to be better at HB0206 due to its proximity to the new reference station, length of the time series, and age of the observations (Table 4). Note that ebb current amplitudes at HB0206 are under-predicted during neap conditions, but timing of the flood current amplitudes are better than when referenced to San Francisco Bay Entrance (Figure 29). Timing of slacks is slightly better when referenced to the Humboldt Bay Entrance station. The predictions, when referenced to the Humboldt Bay Entrance station, are better during an average spring tide at HB0206

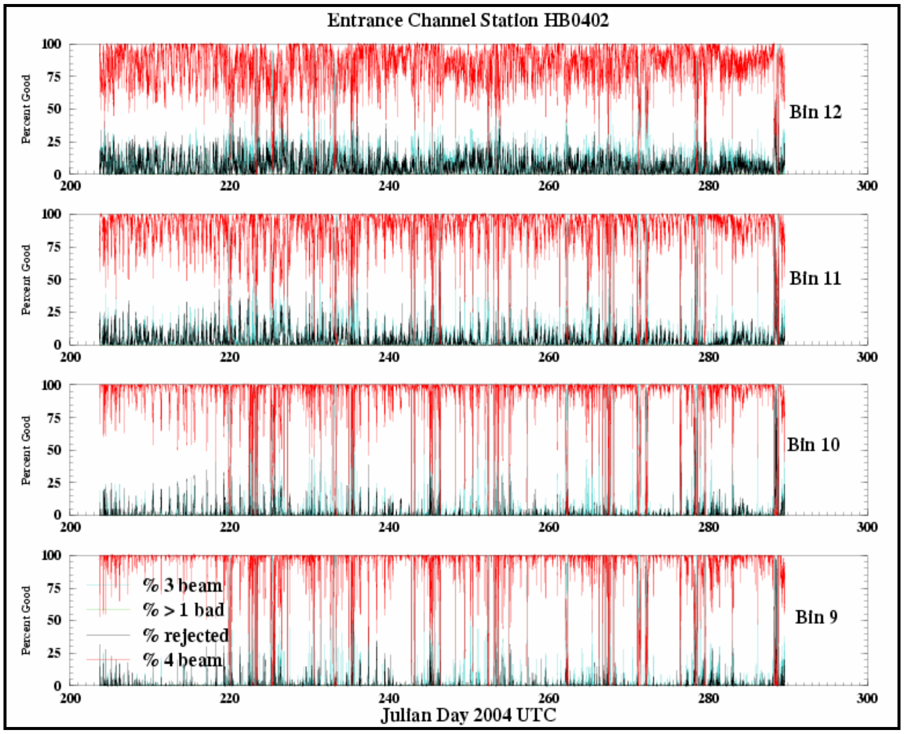

Figure 28. Percent good pings at the Entrance Channel station, HB0402.

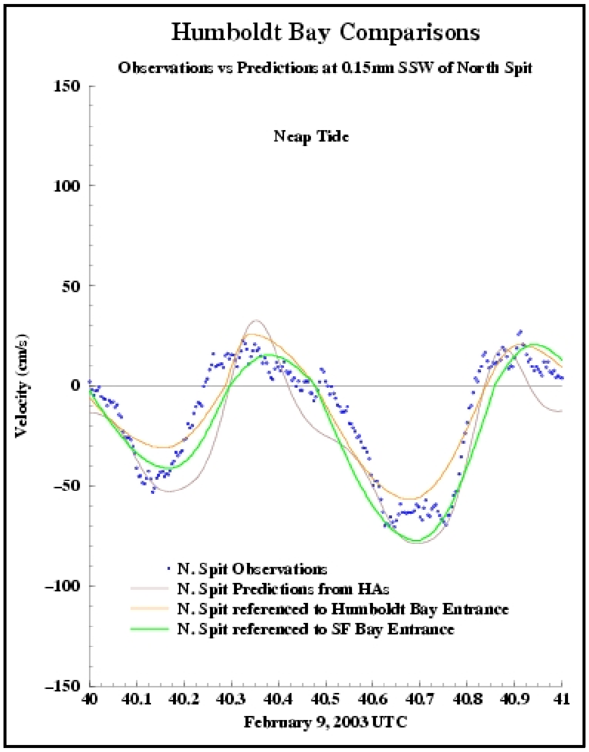

Figure 29. Comparison of tidal current predictions and observations at HB0206 during a neap tide.

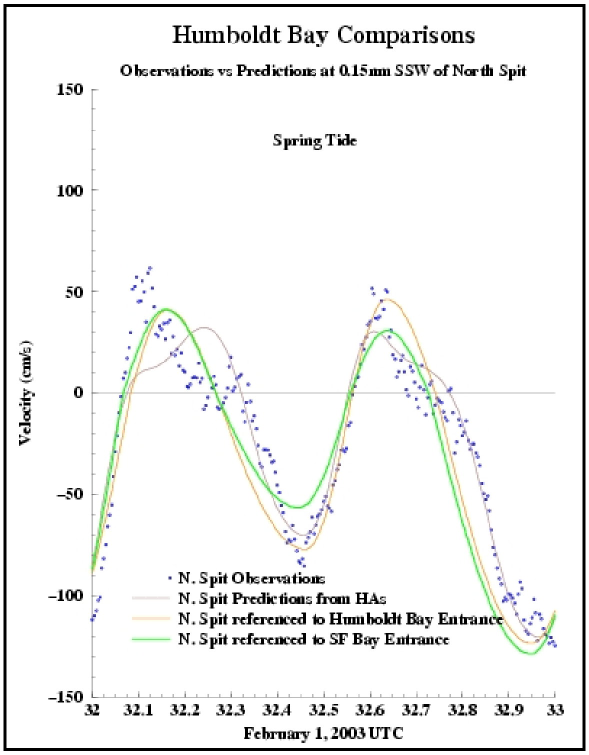

Figure 30. Comparison of tidal current predictions and observations at HB0206 during a spring tide. Each tick mark is 36 minutes.

(see February 1, 2003 in Figure 30). Predictions referenced to SF Bay Entrance and Humboldt Bay Entrance Channel are shown in Figures 31 and 32 for a typical neap and spring tide at the Tosco Pier site located in the northern reach of North Bay Channel. The new reference station appears to do a better job of predicting currents during both neap and spring tides at Tosco Pier (Figures 31 and 32).

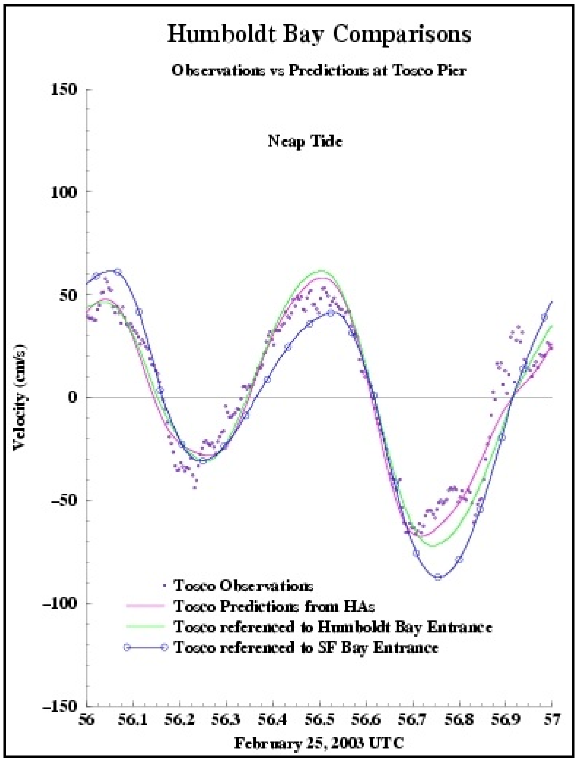

Figure 31. Comparison of predictions and observations at HB0205 during a neap tide. Each tick mark is 36 minutes.

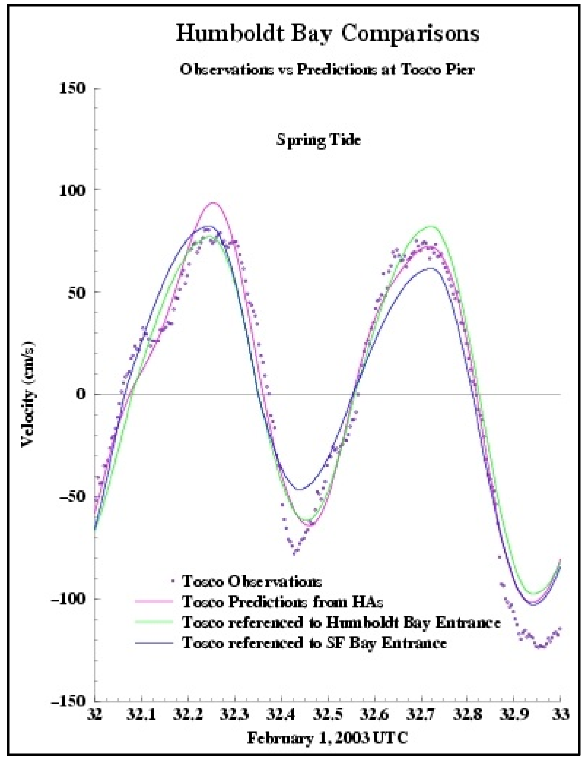

Figure 32. Comparison of predictions and observations at HB0205 during a spring tide. Each tick mark is 36 minutes.

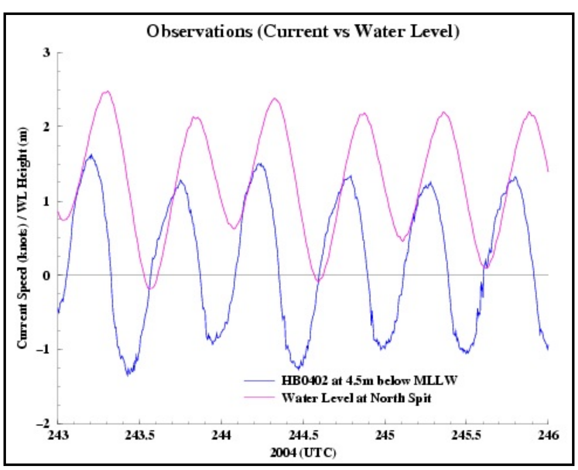

Figure 33. Comparison of observed currents and water level between the jetties of Humboldt Bay.

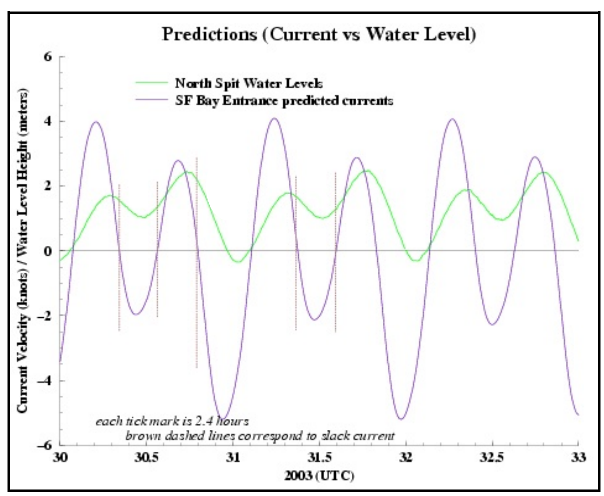

Figure 34. Comparison of predicted currents and water level between the jetties of Humboldt Bay.

In addition, Figure 33 shows the relationship between the nearby National Water Level Observation Network (NWLON) station at North Spit to tidal current observations at the new reference station at HB0402. Note that slack currents (blue line) occur during high water or low water phases of the tide (magenta line) as opposed to being out of phase (brown dashed lines) when compared to SF Bay Entrance (Figure 34). Phase lag difference can be up to 2.4 hours.

Another comparison of predictions to observations is shown in Figure 35 where the non-tidal (residual) current during a neap tide is reported as a root mean square (RMS) of 10.752 cm/s at the reference station (HB0402). Residual current is the difference between self-predicted and observed current where the small RMS indicates that most of the energy is tidal. Other statistics of the proportion of tidal and non-tidal energy are produced when data are detided as in Figure 35 [Zervas, 1999].

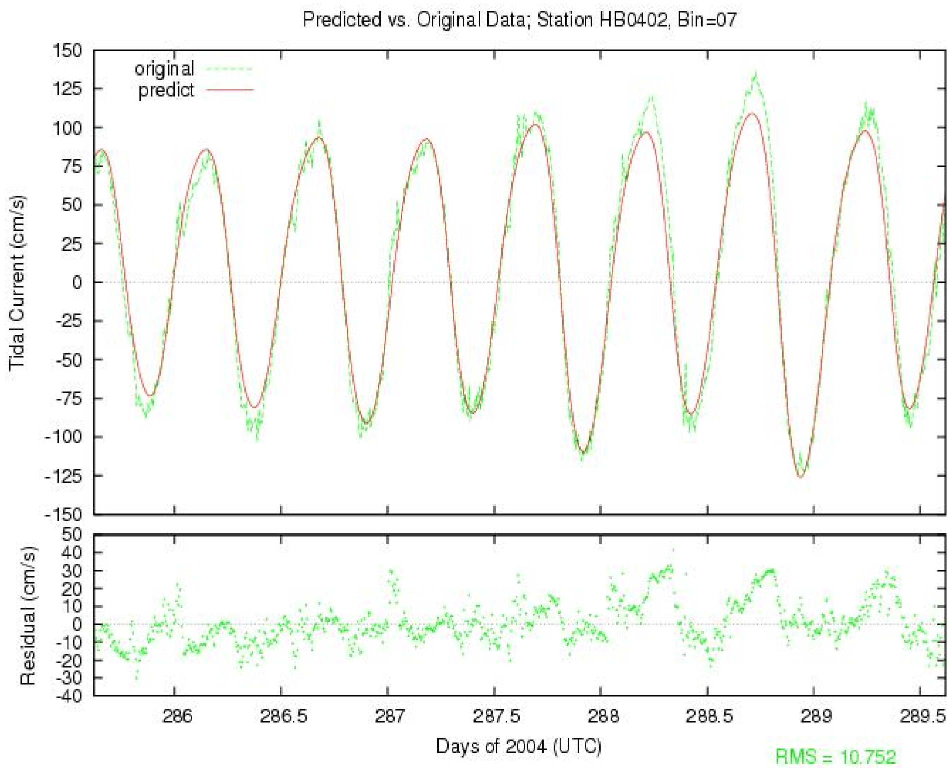

Figure 35. Residual (non-tidal) currents at HB0402 at 4.5 meters below MLLW during a neap tidal current.

Station comparison outside the harbor are summarized in Table 5 where principal current direction indicates the direction along which the main current flow is aligned. Mean maximum currents are the average of all observed maximum current at the selected depth. The maximum observed ebb current speeds were greater at HB0201 than at station HB0401 probably owing to the series of storms that hit the northern coast of California in December 2002. Also, since only 5 days of data were acquired at HB0201 while almost 49 days of data were acquired at HB0401, there's a possibility that data are biased by the small sample size. Currents are normally faster near the surface where bottom friction has less effect.

Table 5. Characteristics of observed currents at selected depths below MLLW outside Humboldt Bay: 2002-2004

STATION			Princpal Current	Mean MFC		MAX MFC		Mean MEC		MAX MEC		Permanent Current	
ID	Location / Description	depth MLLW	dir	spd	dir	spd	dir	spd	dir	spd	dir	speed	dir
		(m)	° T	kt	° T	kt	° T	kt	° T	kt	° T	kt	° T
HB0401	40° 46.013' N 124° 15.179' W	9.3	47	0.32	036	0.72	041	0.47	234	1.15	256	0.045	021
		4.3	50	0.37	045	1.33	052	0.53	235	1.41	260	0.031	015
		2.3	51	0.38	046	1.34	051	0.53	236	1.45	262	0.024	351
		1.3	49	0.40	052	1.32	048	0.48	234	1.52	262	0.009	327
2004 sub-surface buoy; 0.4 nm WNW of south jetty outside Bar Channel													
HB0201	40° 45.973' N 124° 14.815' W	7.9	175	na	na	0.41	194	1.70	001	5.02	355	1.365	004
		4.9	176	na	na	0.33	197	1.71	001	4.39	359	1.457	000
		0.9	166	na	na	0.15	200	1.79	356	4.65	341	1.579	353
2002 sub-surface buoy; ~8.5 meters east of ATON Bell Buoy 2, outside Bar Channel													

The permanent current represents a current that runs continuously and is independent of tides or other temporary causes. Permanent current includes the general surface circulation of the oceans [Zervas, 2000]. The station near ATON Bell Buoy #2, HB0201, occupied during the winter, has a higher permanent current compared to the station occupied in the summer at HB0401 (Table 5) and may be due to the series of coastal storms that passed through Humboldt Bay in December 2002 and January 2003. Note that the permanent current direction for both stations at all depths is to the north.

4.0 PRODUCTS AVAILABLE

User requests for data and products listed in this report are available through the CO-OPS home page and by email at the addresses provided below.

4.1 Data at Multiple Depths at Nine Stations

American Standard Code for Information Interchange (ASCII) data from the seven stations occupied during the 2002/2003 survey and both stations occupied during the 2004 survey are available via data requests through the Predictions Team at: Tide.Predictions@noaa.gov. In the near future, data may be available via the CO-OPS home page at: http://tidesandcurrents.noaa.gov/. Quality control was performed on all velocity data. Harmonic constituents from least squares analysis are available for the stations listed in this report except HB0201 and HB0202, where data were insufficient to run 29 day harmonic analysis. Metadata associated with the data, sensors, and stations are also available. Raw and QC data are available for the following stations:

- *HB0402 - Entrance Channel, 0.25 nm SSE of North Jetty at 34 feet below MLLW*
- *HB0202 - Entrance Channel, 1.0 nm NE of South Spit Light at 14 feet and 30 feet below MLLW*
- *HB0206 - North Spit, 0.15 nm SW of at 15 feet and 32 feet below MLLW*
- *HB0207 - South Spit, 0.1 nm NE of (Entrance to Fields Landing Channel) at 15 feet below MLLW*
- *HB0203 - North Bay Channel, west of Eureka at 15 feet and 28 feet below MLLW*
- *HB0204 - North Bay Channel at Fairhaven Terminal at 13 feet below MLLW*
- *HB0205 - North Bay Channel at Samoa Channel (Tosco Pier) at 15 feet below MLLW*
- *HB0401 - Humboldt Bay Bar Channel, 0.4nmi WNW of s jetty at 14 feet and 31 feet below MLLW*
- *HB0201 - Humboldt Bay Bar Channel, near ATON Bell Buoy #2 (just 5 days at multiple depths*)

4.2 New Reference Station Located in Humboldt Bay

The new reference station is located in the Entrance Channel, 0.25nm SSE of north jetty, at 4.5 meters below mean lower low water (MLLW). Daily predictions of this station in the Entrance Channel to Humboldt Bay will appear in the 2006 Tidal Current Tables - Pacific Coast of North America and Asia. This station replaces the existing reference station, San Francisco Bay Entrance, for those stations located within Humboldt Bay that were occupied during the 2004 survey. The station located outside the harbor (HB0401) is also referenced to this new station.

4.3 New Secondary Stations within Humboldt Bay

Since more than 30 days of data were acquired at each of the 2002/2003 stations, these secondary station designations apply to only the Tidal Current Tables. Harmonic constituents were generated and users can request "special" harmonic predictions for all of the stations to the Prediction Team at: Tide.Predictions@noaa.gov. Five new secondary stations were acquired during the 2002/2003 survey in addition to two stations in 2004. The five secondary stations appeared in Table 2 of the 2004 Tidal Current Tables. The Entrance Channel station from the 2002 survey, HB0202, was deemed acceptable as a secondary station after data comparison to newly acquired data from a nearby station, HB0402. The following two new secondary stations are to appear in Table 2 of the 2006 Tidal Current Tables - Pacific Coast of North America and Asia.

- HB0402 - Entrance Channel, 0.25nm SSE of North Jetty at 34 feet below MLLW

- HB0202 - Entrance Channel, 1nm NE of South Spit Light at 14 feet and 30 feet below MLLW

4.4 New Secondary Stations outside Humboldt Bay

Only one new secondary station outside the harbor will appear in the 2006 Tidal Current Tables - Pacific Coast of North America and Asia. Two depths will be reported in the Tidal Current Tables.

- HB0401 - Humboldt Bay Bar Channel, 0.4nmi WNW of s jetty at 14 feet and 31 feet below MLLW

4.5 Acquisition of Data During an El Nino Event

Storm data during *The El Nino*, 2002/2003, are available for one station outside the harbor and one station within the harbor. As noted in Table 1 of this report, the data were compromised at HB0201 due to the storm and excessive tilts. In addition, the subsurface buoy departed its mooring shortly after deployment. The station within the harbor, HB0202, acquired about 21 days of good data and was also buried by sediment transport through the Entrance Channel. Data from these two stations exhibit the extremes encountered when a series of storms hit the northern coast of California during the winter of 2002/2003.

4.6 Updated Predictions in Humboldt Bay

Predictions from the five stations mentioned in Section 4.3 have been updated with new time differences and speed ratios in Table 2 of the 2006 Tidal Current Tables and are summarized in Table 6. A new reference station within Humboldt Bay replaces the existing station at San Francisco Bay Entrance and all newly occupied stations within Humboldt Bay are referenced to this new station at Humboldt Bay Entrance Channel, 0.25nm SSE of north jetty, at 4.5 meters MLLW.

Table 6. Table 2 of speed ratios and time differences for Humboldt Bay stations referenced to Humboldt Bay Entrance Channel from the 2006 NOS Tidal Current Tables - Pacific Coast of North America and Asia.

No.	PLACE	Meter Depth	POSITION		TIME DIFFERENCES				SPEED RATIOS		AVERAGE SPEEDS AND DIRECTIONS							
			Latitude	Longitude	Min. before Flood	Flood	Min. before Ebb	Ebb	Flood	Ebb	Minimum before Flood		Maximum Flood		Minimum before Ebb		Maximum Ebb	
		ft	North	West	h m	h m	h m	h m			knots	Dir.	knots	Dir.	knots	Dir.	knots	Dir.
	CALIFORNIA COAST Time meridian, 120° W				on San Francisco Bay Ent., p.8													
946	Point Reyes <13>		38° 00'	123° 02'	−1 12	−1 12	−1 12	−1 12	0.3	0.3	--	--	1.1	320°	--	--	1.1	140°
951	Salt Point <13>		38° 34'	123° 21'	−1 20	−1 20	−1 20	−1 20	0.3	0.3	--	--	0.9	325°	--	--	0.9	145°
956	Point Arena <13>		38° 57'	123° 45'	−1 29	−1 29	−1 29	−1 29	0.3	0.3	--	--	1.1	330°	--	--	1.1	150°
961	Point Cabrillo <13>		39° 21'	123° 50'	−1 38	−1 38	−1 38	−1 38	0.3	0.3	--	--	1.0	345°	--	--	1.0	165°
966	Cape Vizcaino <13>		39° 44'	123° 50'	−1 48	−1 48	−1 48	−1 48	0.3	0.3	--	--	0.9	325°	--	--	0.9	145°
971	Point Delgada <13>		40° 00'	124° 04'	−1 37	−1 37	−1 37	−1 37	0.3	0.3	--	--	1.0	325°	--	--	1.0	145°
976	Punta Gorda <13>		40° 15'	124° 22'	−1 36	−1 36	−1 36	−1 36	0.3	0.3	--	--	1.1	335°	--	--	1.1	155°
981	Cape Mendocino Light, 4.6 mi. W of <14>		40° 26'	124° 30'	---	---	---	---	--	--	--	--	--	--	--	--	--	--
986	Table Bluff Light <13>		40° 42'	124° 17'	−1 11	−1 11	−1 11	−1 11	0.3	0.3	--	--	0.8	010°	--	--	0.8	190°
	HUMBOLDT BAY				on Humboldt Bay Entr. Channel, p.32													
991	Humboldy Bay Bar Channel, 0.4 nm WNW of	4d	40° 46.01'	124° 15.18'	−0 29	−1 13	−0 41	−0 37	0.2	0.3	0.1	329°	0.4	048°	0.1	154°	0.5	232°
	...do.	31d	40° 46.01'	124° 15.18'	−0 39	−1 23	−0 25	−0 58	0.2	0.3	0.2	334°	0.3	041°	--	--	0.4	230°
996	HUMBOLDT BAY ENTRANCE CHANNEL	15d	40° 45.91'	124° 14.26'		*Daily predictions*					--	--	1.7	140°	0.1	050°	1.5	323°
	...do.	34d	40° 45.91'	124° 14.26'	−0 13	−0 01	−0 02	−0 06	0.8	0.7	--	--	1.3	141°	--	--	1.1	323°
1001	Humboldt Bay Entr., 0.1 nm NE of South Spit Light	14d	40° 45.47'	124° 13.97'	+0 55	−0 15	−0 17	+0 21	0.9	1.4	0.1	072°	1.6	168°	--	--	2.2	341°
	...do.	30d	40° 45.47'	124° 13.97'	+0 55	−0 13	−0 15	+0 21	0.9	1.3	0.1	078°	1.5	171°	--	--	2.1	346°
1006	North Spit, 0.15 n.mi. SW of	15d	40° 45.47'	124° 13.37'	+0 19	−1 57	−2 01	+0 16	0.4	1.1	0.1	155°	0.6	073°	--	--	1.6	243°
	...do.	32d	40° 45.47'	124° 13.37'	+0 05	−2 09	−2 11	+0 09	0.3	0.8	--	--	0.5	070°	--	--	1.3	257°
1011	South Spit, 0.1 n.mi. E of	15d	40° 44.87'	124° 13.45'	+0 10	−0 52	−0 47	+0 20	0.5	0.8	--	--	0.8	178°	0.1	086°	1.2	002°
1016	North Bay Channel, west of Eureka	15d	40° 47.23'	124° 11.56'	+0 40	+0 01	+0 00	+0 21	0.9	1.2	--	--	1.6	021°	--	--	1.8	197°
	...do.	28d	40° 47.23'	124° 11.56'	+0 16	−0 10	−0 02	+0 10	0.8	0.9	--	--	1.4	013°	0.1	286°	1.4	200°
1021	North Bay Channel at Fairhaven	13d	40° 47.24'	124° 11.66'	+0 18	+0 05	−0 11	+0 07	0.8	1.2	--	--	1.3	030°	--	--	1.8	216°
1026	North Bay Channel at Samoa Channel	15d	40° 47.77'	124° 11.24'	+0 14	+0 08	+0 00	+0 05	0.8	0.9	--	--	1.2	015°	--	--	1.3	196°
	CALIFORNIA COAST–cont.				on San Francisco Bay Ent., p.8													
1031	Trinidad Head <13>		41° 03'	124° 10'	−0 57	−0 57	−0 57	−0 57	0.3	0.3	--	--	1.0	005°	--	--	1.0	185°
1036	Redding Rock Light <13>		41° 21'	124° 11'	−0 52	−0 52	−0 52	−0 52	0.3	0.3	--	--	0.9	010°	--	--	0.9	190°
1041	St. George Reef <13>		41° 49'	124° 20'	−0 41	−0 41	−0 41	−0 41	0.3	0.3	--	--	1.0	005°	--	--	1.0	185°

Endnotes can be found at the end of table 2.

References

[1] NOAA's current program field operations manual, Spring 2003

[2] K. Earwaker, D. McNally, E. Shih, A field study of horizontal current profilers, MTS/IEEE 2002 Conference presentation, October 2002.

[3] C. Zervas, NOS tide and current glossary, NOS CO-OPS report, 2000.

[4] C. Zervas, Tidal current analysis procedures and associated computer programs, March 1999.

5.0 FUTURE WORK

The Humboldt Bay Harbor District expressed an interest in a real time system that would disseminate data every six minutes from multiple sites to promote safe navigation in the harbor. A decision about implementing a Physical Oceanographic Real Time System (PORTS®) in the harbor may occur after the mariners have sufficient time to use and evaluate the updated predictions. An example of graphical images displayed to the public are shown at this PORTS link, [http://tidesandcurrents.noaa.gov/ports.html] and accessed from the CO-OPS web page at: http://tidesandcurrents.noaa.gov. The Entrance Channel is dredged by the U.S. Army Corps of Engineers (USACE) every fall and spring when warranted, which may require periodic updating of the predictions due to changes in controlling channel depths and bathymetric contours. Humboldt Bay is a dynamic area where a real time system of sensors may benefit the marine community and promote safe navigation through the harbor.

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