B.1 DATA COLLECTION SUMMARY

B.1.1 Moored Current Meters (Velocity Profiles)

Four upward-looking Acoustic Doppler Current Profilers (ADCPs) were installed within the East Waterway (EW); one in the Sill Reach south of the bridges, and three in the Main Body Reach (see Figure 2-3). The current meters were installed in four deployments between May 7 and August 18, 2009, with temporary retrievals on May 20, June 24, and July 28, 2009, during which data were downloaded and diagnostic checks were performed to confirm proper operation. All times and dates are referenced to Universal Coordinated Time (UTC). Table B-1 outlines the instrumentation, sampling rate, and vertical resolution for the four current meters. Table B-2 lists the locations and approximate water depths at deployment for each of the current meters for each deployment. Figure 1-6 in the main body of the report shows the location of the moored current meters.

Table B-1
ADCP Instrumentation and Setup Details

Station	Instrumentation	Sampling Rate (min)	Averaging Period(s)	Vertical Resolution (m)	Number of Vertical Bins
1 (North)	Nortek 600 kHz AWAC	10	180	1.0	50
2 (Middle)	Sontek 500 kHz ADCP	10	120	1.0	24
3 (South)	RDI 1200 kHz ADCP	10	600	0.5	23
4 (Junction)	RDI 1200 kHz ADCP	10	600	0.5	23

Table B-2
ADCP Deployment Times and Locations

Station	Deployment	Latitude (DMS)	Longitude (DMS)	Water Depth at Deployment (m)
1 (North)	1	47° 35’ 14.0520”	122° 20’ 41.7780”	16.7 (54 ft)
	2	47° 35’ 13.9242”	122° 20’ 39.1424”	17.9 (58 (ft)
	3	47° 35’ 13.8852”	122° 20’ 39.1111”	18.5 (60 ft)
	4	47° 35’ 14.0053”	122° 20’ 39.5096”	15.0 (49 ft)
2 (Middle)	1	47° 34’ 45.3420”	122° 20’ 40.6860”	16.7 (54 ft)
	2	47° 34’ 45.6416”	122° 20’ 38.5395”	18.0 (59 ft)
	3	47° 34’ 45.4986”	122° 20’ 38.5722”	15.2 (49.8 ft)
	4	47° 34’ 45.3177”	122° 20’ 38.8685”	15.2 (49.8 ft)

Station	Deployment	Latitude (DMS)	Longitude (DMS)	Water Depth at Deployment (m)
3 (South)	1	47° 34' 20.7900"	122° 20' 41.3340"	7.6 (24 ft)
	2	47° 34' 20.8573"	122° 20' 41.4859"	10.3 (33 ft)
	3	47° 34' 20.8032"	122° 20' 41.6560"	7.6 (24 ft)
	4	47° 34' 20.3944"	122° 20' 41.6036"	7.0 (23 ft)
4 (Junction)	1	47° 34' 10.3080"	122° 20' 45.8520"	7.6 (24 ft)
	2	47° 34' 10.4970"	122° 20' 45.6173"	8.0 (26 ft)
	3	47° 34' 10.8940"	122° 20' 45.1922"	7.6 (24 ft)
	4	47° 34' 10.8940"	122° 20' 45.1922"	7.1 (23 ft)

B.1.2 Velocity Transects

Velocity transects were obtained over a 24-hour period between May 13 and May 14, 2009, using a pole-mounted, downward-facing Teledyne RDI 600 kHz ADCP mounted on the starboard side of the sampling vessel. The instrument was submerged approximately 1.0 meter (m) below the water surface to move the sensors away from the wake created by the sampling vessel while underway. One set of transects (three perpendicular to the EW channel and one along the EW channel) was completed within 1 hour to obtain synoptic velocity measurements representative of a single phase of the tide. A total of 16 sets of transects (64 total profiles) were completed during the 24-hour sampling period. Table B-3 outlines the sample times and approximate tidal stage for the velocity transect data. Figure 1-6 in the main body of the report shows the locations of the transects.

Table B-3

Sampling Times and Tide Stages for Velocity Transect Measurements

Transect Round #	Date (UTC)	Time (UTC)	Tidal Stage
1	5/13/2009	18:57 to 20:04	Ebb to low slack
2	5/13/2009	20:16 to 21:19	Low slack
3	5/13/2009	22:13 to 23:30	Low slack to flood
4	5/14/2009	00:03 to 01:03	Flood
5	5/14/2009	01:12 to 02:15	Flood
6	5/14/2009	02:56 to 03:59	Flood to high slack
7	5/14/2009	04:55 to 06:05	High slack
8	5/14/2009	06:49 to 08:14	High slack to ebb
9	5/14/2009	08:32 to 09:43	Ebb to low slack

Transect Round #	Date (UTC)	Time (UTC)	Tidal Stage
10	5/14/2009	09:47 to 10:47	Low slack
11	5/14/2009	11:51 to 12:59	Flood
12	5/14/2009	13:03 to 14:16	Flood to high slack
13	5/14/2009	14:20 to 15:16	High slack
14	5/14/2009	15:20 to 16:23	High slack to ebb
15	5/14/2009	16:28 to 17:26	Ebb
16	5/14/2009	17:31 to 18:37	Ebb

B.1.3 Salinity Profiles

Salinity profiles were obtained using a Hydrolab DS5 conductivity temperature depth (CTD) meter during the velocity transect data collection. The locations of the salinity profiles were co-located with three of the four moored ACDPs: Stations 1, 2, and 3 north of the Junction Reach. Sixteen CTD casts at each of the three identified locations were completed in the 24-hour sampling period. Table B-4 provides the sampling times and approximate tidal stage for each of the CTD casts. Figure 1-6 in the main body of the report shows the location of the salinity profiles.

Table B-4
Sampling Times and Tide Stages for CTD Measurements

Cast Round #	Date (UTC)	Time (UTC)	Tidal Stage
1	5/13/2009	19:05 to 19:39	Ebb
2	5/13/2009	20:21 to 20:55	Low slack
3	5/13/2009	22:21 to 23:05	Low slack to flood
4	5/14/2009	00:09 to 00:40	Flood
5	5/14/2009	01:17 to 01:48	Flood
6	5/14/2009	03:03 to 03:34	Flood to high slack
7	5/14/2009	05:04 to 05:40	High slack
8	5/14/2009	07:03 to 07:51	Ebb
9	5/14/2009	08:43 to 09:17	Ebb
10	5/14/2009	09:52 to 10:21	Low slack
11	5/14/2009	11:57 to 12:29	Low slack to flood
12	5/14/2009	13:09 to 13:43	Flood
13	5/14/2009	14:26 to 14:53	High slack

Cast Round #	Date (UTC)	Time (UTC)	Tidal Stage
14	5/14/2009	15:26 to 16:01	High slack to ebb
15	5/14/2009	16:34 to 17:06	Ebb
16	5/14/2009	17:37 to 18:14	Ebb

B.1.4 Tide Gauge

A Paros Digi-quartz pressure sensor was installed in the Junction Reach near ADCP Station 4, mounted onto a stable wood piling on the northernmost dock south of the Spokane Street Bridge on the west side of the EW, in order to measure water levels during the instrument deployment. The tide gauge was deployed between May 8 and August 18, 2009, with intermediate data retrievals occurring on May 21, June 21, and July 27, 2009. The gauge was located at coordinates 47° 34' 13.5000" N, 122° 20' 45.4500" W, with an elevation of -2.324 m North American Vertical Datum of 1988 (NAVD88) determined by a 2.5-hour static differential global positioning system (DGPS) observation. It collected samples at a rate of 10 minutes using a 120-second averaging period. Figure 1-6 in the main body of the report shows the location of the tide gauge.

B.2 DATA SUMMARY

Reports detailing the instrument deployments and presentation of the collected data were produced by Evans Hamilton, Inc. (EHI 2009a, 2009b, and 2009c) and are included in this appendix as Attachments 1 (deployments 1 and 2), Attachment 2 (deployment 3), and Attachment 3 (deployment 4).

B.3 DEVIATIONS FROM THE SEDIMENT TRANSPORT CHARACTERIZATION QAPP

The Sediment Transport Characterization Quality Assurance Project Plan (QAPP; Anchor QEA 2009, Section 3.1.3) outlines the required data collection procedures and locations for velocity and salinity data. There were no significant deviations from the QAPP that altered the quality of data collected. On the contrary, additional data were collected within the EW that were beyond the requirements laid out in the QAPP. An additional moored ADCP was placed in the Junction Reach, near the confluence of the EW with the Lower Duwamish Waterway (LDW). This ADCP was included to provide additional spatial resolution in the velocity profile data, and to obtain velocity information as close as possible to the upstream

mouth of the EW. A tide gauge was placed in the EW to obtain precise measurements of water levels during the data collection period; this was not a requirement in the QAPP.

Table 3-3 in the QAPP provides proposed locations and water depths for the three moored current meters (not including the location in the Junction Reach) and salinity profiles (these were co-located). Actual water depths and locations for the current meters varied slightly, but not significantly, from those proposed due to updated bathymetry data (collected as part of the Sediment Transport Evaluation), variations in the bed elevation, and navigation concerns. In particular, Locations 1 and 2 (in the Main Body Reach north of Slip 27) were moved slightly between deployments 1 and 2 due to concerns that the current meters would be hit by passing ships at lower tides. Table B-2 provides updated locations and water depths for each instrument and deployment.

REFERENCES

Anchor QEA, 2009. East Waterway Operable Unit, Supplemental Remedial Investigation/Feasibility Study, Final Sediment Transport Characterization Quality Assurance Project Plan. Prepared for Port of Seattle. March.

EHI, 2009a. Evans Hamilton, Inc. East Waterway, Oceanographic Data Collection, Deployment 1 & 2 Data Report. Prepared for Anchor QEA, LLC. July 2009.

EHI, 2009b. Evans Hamilton, Inc. East Waterway, Oceanographic Data Collection, Deployment 3 Data Report. Prepared for Anchor QEA, LLC. September 2009.

EHI, 2009c. Evans Hamilton, Inc. East Waterway, Oceanographic Data Collection, Deployment 4 Data Report. Prepared for Anchor QEA, LLC. October 2009.

EVANS-HAMILTON, INC.

DUWAMISH RIVER – EAST WATERWAY

OCEANOGRAPHIC DATA COLLECTION

DEPLOYMENT 1 DATA REPORT

JULY 2009

PREPARED FOR

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DUWAMISH RIVER – EAST WATERWAY OCEANOGRAPHIC DATA COLLECTION DEPLOYMENT 1 DATA REPORT CONTENTS

DUWAMISH RIVER – EAST WATERWAY

CONTENTS CONTINUED

APPENDICES

TABLES

FIGURES

1.0 INTRODUCTION

Evans-Hamilton, Inc. (EHI) conducted field measurements in support of the Anchor QEA, LLC project East Waterway Supplemental Remedial Investigation and Feasibility Study for the Port of Seattle. The field measurements consisted of deploying four current measurement systems, installing one water level gauge, and conducting real-time current profiles in the East Waterway (EWW) of the Duwamish River in Seattle, WA. The instrument locations and proposed transect locations were pre-determined according to the map below (Figure 1). The four bottom mounted current meters are to occupy their respective locations for approximately three months with periodic service and downloads. A temporary water level gauge (tide station) was installed south of the Spokane Street Bridge to collect water level data concurrent with this study. A real-time over-the-side (OTS) current profile survey was conducted within a week after the initial deployment of the current meters. This report summarizes the deployment and recovery of the instruments as well as the OTS survey performed during Deployment 1.

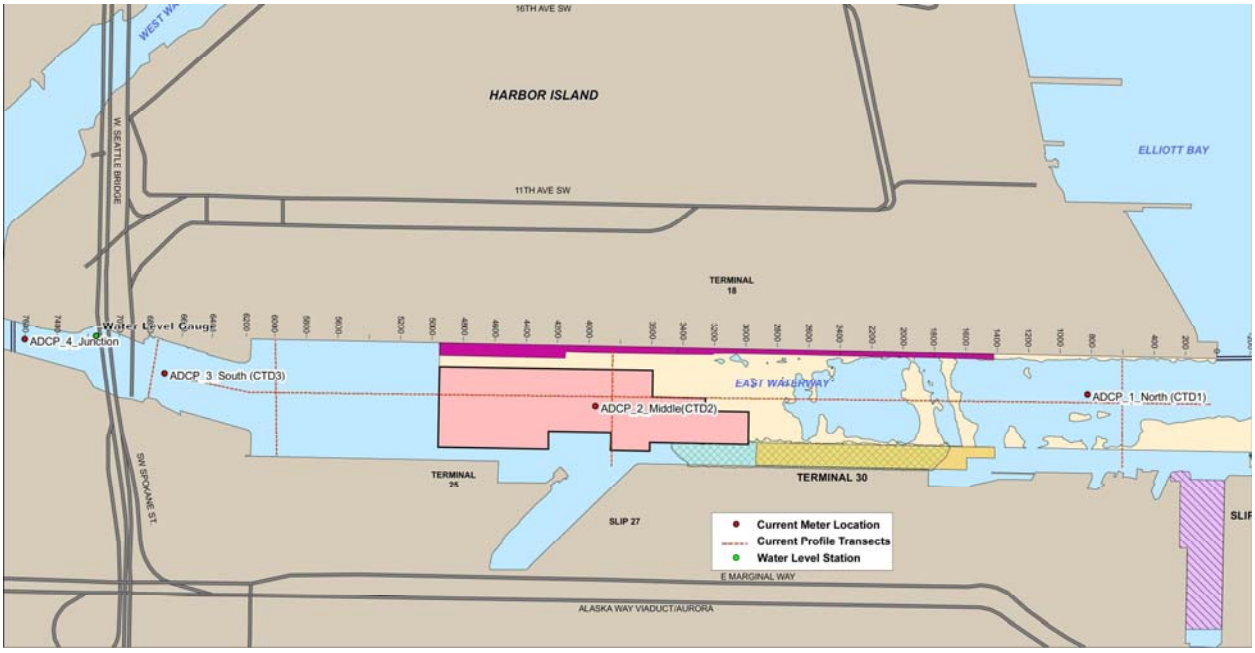

Figure 1. Current meter, water level gauge, and current profile transect locations.

2.0 EQUIPMENT AND FIELD PROCEDURES

All field equipment was assembled and tested at EHI's Seattle, WA facility. This included calibrating the current meter compasses, calibrating the CTD sensors against known standards, and referencing all pressure sensors to zero. All instrument clocks were synced to Coordinated Universal Time (UTC). All current meters were stepped through a check out procedure, and final verification of settings. Table 1 summarizes the instrument settings.

Table 1. Instrumentation and setups.

Site	Instrumentation	Sample rate (minutes)	Depth cell size (m)	Number of bins
Station 1 (North)	Nortek 600 kHz AWAC	10 (180 second average)	1.0	50
Station 2 (Middle)	Sontek 500 kHz ADP	10(120 second average)	1.0	24
Station 3 (South)	RDI 1200 kHz ADCP	10 (600 second average)	0.5	23
Station 4 (Junction)	RDI 1200 kHz ADCP	10 (600 second average)	0.5	23
Tide Station (Junction)	Paros Digi-quartz Sensor	10 (120 second average)	---	---

2.1 Deployments

Initial deployment of the current meters occurred on 7 May 2009. Prior to deployment of the current meter mounts, the water depth was verified using the vessel fathometer to ensure water depth coincided with the set-up parameters of the ADCP for that site. Once the boat was on location and stable, the bottom mounts were lowered to the seabed and a positional fix was taken prior to the deployment line being pulled free of the bottom mount. This procedure worked well and was repeated at each deployment site. The navigation system was configured with antenna and compass offset to calculate final deployment positions at the vessel's A-frame (deployment point). Geodetic parameters are WGS-84, additional grid coordinates were collected in WASP North, UNITS: feet. Table 2 lists the deployment locations for all sites.

Installation of the water level gauge occurred the following day on 8 May 2009. The water level gauge (tide gauge) consisted of a Paros pressure-sensor mounted onto a stable wood piling on the northern most dock south of the Spokane Street Bridge on the west side of the waterway. The sensor cable was run up the piling to a topside data logger housed in a weather proof enclosure on the top of the dock. The elevation of the pressure sensor was surveyed to a benchmark (survey-flagged re-enforcement rod) onshore to tie it into a known elevation datum. Survey data could not be recovered for the benchmark; therefore EHI performed a 2.5 hour static DGPS observation on the benchmark on 21 May 2009 using a THALES logging DGPS. The logged data file was submitted to Online Positioning User Service (OPUS - http://www.ngs.noaa.gov/OPUS/) to obtain preliminary elevation data of the benchmark and hence the tide gauge.

At the request of the Port of Seattle, the current meter mounts were pulled two weeks following initial deployment to ensure the meters were functioning properly and data was being collected. The four current meter mounts were retrieved, serviced, and redeployed on 20 May 2009. During the mount service, the systems were checked and bio-fouling cleaned if required. The current meters were downloaded, data and operation evaluated, and then set-up for Deployment 2. The tide station data was downloaded on 21 May 2009 during the DGPS static observation on the benchmark.

Review of the data in the field showed all instruments operating as programmed. Low current velocities of less than 25 cm/s (half a knot) were observed the majority of the time, especially at sites 1, 2, and 3. Ship and barge traffic is evident in the fluctuations observed in the compass data. One of the transducer beams (Beam 1) on the current meter at Station 1 exhibited a temporary signal obstruction for one day. Speculation is it was probably due to biologic interference such as a starfish or deposited debris after a ship passage.

Prior to redeployment, all current meters were stepped through the check out procedure and a final verification of settings. No changes were made to instrument sampling settings other than time synchronization and start times. All bottom mounts were redeployed using the same method as the first deployment. Due to some expressed concern for our instrumentation from the Puget Sound Pilot's Association, such as potential crushing or toppling of instruments by a large container ship during low tides, Station 1 and Station 2 were moved farther east of the centerline than Deployment 1. These locations are included in Table 2.

Approximately one month following redeployment, the four current meter mounts were retrieved on 24 June 2009. During this service trip, the systems were checked, cleaned for bio-fouling, and the meters were downloaded. All meters functioned properly and contained full data sets. The tide station data was downloaded on 21 June 2009.

Table 2. Deployment 1 and 2 station locations.

Site	**Latitude** (Deg. Min. Sec.)	**Longitude** (Deg. Min. Sec.)	**Deployment Date** (UTC)	**Recovery Date** (UTC)	**Water Depth** (Meters, at Deployment)
Deployment 1					
Station 1	47° 35' 14.0520"	122° 20' 41.7780"	05/07/2009	05/20/2009	16.7
Station 2	47° 34' 45.3420"	122° 20' 40.6860"	05/07/2009	05/20/2009	16.7
Station 3	47° 34' 20.7900"	122° 20' 41.3340"	05/07/2009	05/20/2009	7.6
Station 4	47° 34' 10.3080"	122° 20' 45.8520"	05/07/2009	05/20/2009	7.6
Tide Station	47° 34' 13.5000"	122° 20' 45.4500"	05/08/2009	05/21/2009	---
Deployment 2					
Station 1	47° 35' 13.9242"	122° 20' 39.1424"	05/20/2009	06/24/2009	17.9
Station 2	47° 34' 45.6416"	122° 20' 38.5395"	05/20/2009	06/24/2009	18.0
Station 3	47° 34' 20.8573"	122° 20' 41.4859"	05/20/2009	06/24/2009	10.3
Station 4	47° 34' 10.4970"	122° 20' 45.6173"	05/20/2009	06/24/2009	8.0
Tide Station	47° 34' 13.5000"	122° 20' 45.4500"	05/21/2009	06/21/2009	---

2.2 Over-the-Side Current Profiling Survey

Real-time OTS current data was collected along four (4) pre-determined transect locations in the EWW over a tidal day (twenty-four hours) beginning around 1100 hrs (PDT) 13 May 2009 and finishing around 1200 hrs (PDT) 14 May 2009. Three of the transects were run perpendicular to the waterway near the approximate positions of Station 1 and Station 2 and approximately 800 feet north of Station 3. The later transect location was due to channel width restriction from parked barges. A fourth transect was run from

south to north near the centerline of the waterway beginning south of Station 3 and terminating just north of the entrance into the waterway (see Figure 1).

The OTS survey was conducted using a pole-mounted downward facing Teledyne RDI 600 kHz ADCP mounted on the starboard side of the vessel. Calibration of the system was performed on site before data collection began. Due to the draft of the vessel and a potential for noise induced by the propeller wash, the transducer head of the ADCP was placed 1.0-meters below the water surface. The DGPS antenna was mounted on top of the pole directly above the ADCP to provide position accuracy. The DGPS position data feed was split between two (2) systems in the cabin. The first system, for navigation, was configured with antenna and compass offsets allowing the crew to observe the vessel position and heading along the transect. This also provided a helm display for the vessel's operator to steer by and maintain a good relative course along each transect. The second system recorded and displayed real-time current profile and position data using Teledyne RDIs' WinRiver software as the vessel transited each transect.

At the completion of each east-west transect, the boat would maneuver into a position where the along channel transect intersected the centerline of the waterway (south to north transect) and a CTD cast made. In-situ water quality data including parameters such as temperature, salinity/conductivity, turbidity, dissolved oxygen, and pH were recorded through the water column at each bottom mounted ADCP location.

Due to the slow water velocities observed, the vessel tried to maintain a very low transit speed to maintain data quality during each transect. This transit speed yielded collection of all four transects typically in just over one hour. Transects were delayed on a few occasions due to vessel traffic. All totaled sixteen (16) rounds or sixty-four (64) transects were collected.

3.0 Data Processing and Analysis

The data has undergone processing using EHI standard routines. Data plots and tables have been generated as well as text files of the data. The organization of the data products within the appendices, along with notes concerning each type of data product, is provided below. All times are referenced to UTC.

Text files of the processed data are available via the EHI ftp site. File format and units are provided at the start of each data file. Bad or missing data (typically near the surface bins) are designated with 999.9.

3.1 Station 1 – Appendix A

Deployed at station 1 was a 600 kHz AWAC (Nortek). The mount was moved 181 ft east for the second deployment placing it 1.2m deeper in depth compared to deployment 1. Data were collected in 1 m depth bins. The average depth of the meter was 18.4m. The first bin after blanking is 16.4m below the water surface. The AWAC data reach to the water surface. The last bin with a full set of usable data is 2.8 m below the surface although data were collected intermittently at shallower depths during higher water periods.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Conversion of cm/s to feet/s: 30.48 cm/s = 1 ft/s.

Color contours of data quality parameters for vertical velocity and for each beam of the transducer heads of signal amplitude versus depth and time. Oscillating red lines in amplitude graphs indicate the boundary layer or water surface. Bottom graph is time history plot of average vertical velocity (cm/s) through the water column. Velocities are in cm/s. Amplitude is in counts. Note the visible white space (vertical velocity) and blue space (amplitude) in the color contours during 18-19 May. This is the day long period when one of the transducer beams was obstructed and the data signal could not be resolved. Also note the thin white line in the color contours at 20 May. This is the short period when the mooring was pulled after the two week deployment 1 interval

Time history plots of water level (pressure sensor in m), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees True), and heading from the compass (degrees).

Time series vector plots of the measured currents at selected depths referenced to north. The length of the vector is equal to the speed of the current according to the speed scale (in cm/s). The direction of the vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

Percent occurrence tables for each measured depth bin. Table shows the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

Current roses of percent occurrence of current speed versus direction for each depth shown in the time series vector plots. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

3.2 Station 2 – Appendix B

Deployed at station 2 was a 500 kHz ADP (Sontek). The mount was moved 148 ft east for the second deployment placing it 1.3m deeper in depth compared to deployment 1. Data were collected in 1 m depth bins. The average depth of the meter was 18.9m. The first bin after blanking is 16.9m below the water surface. The ADP data reach to the water surface. The last bin with a full set of usable data is 1.9 m below the surface although data were collected intermittently at shallower depths during higher water periods.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Conversion of cm/s to feet/s: 30.48 cm/s = 1 ft/s.

Color contours of data quality parameters for each beam of the transducer heads of signal-to-noise ratio (SNR) and signal amplitude versus depth and time. Signal-to-noise is in dB. Amplitude is in counts.

Oscillating lines (light blue in SNR and red in amplitude) in graphs indicate the boundary layer or water surface. Note the visible white line in the color contours at 20 May. This is the short period when the mooring was pulled after the two week deployment 1 interval.

Time history plots of water level (pressure sensor in m), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees True), and heading from the compass (degrees).

Time series vector plots of the measured currents at selected depths referenced to north. The length of the vector is equal to the speed of the current according to the speed scale (in cm/s). The direction of the vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

Percent occurrence tables for each measured depth bin. Table shows the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

Current roses of percent occurrence of current speed versus direction for each depth shown in the time series vector plots. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

3.3 Station 3 – Appendix C

Deployed at station 3 was a 1200 kHz ADCP (Teledyne RDI). Although the mount was redeployed for deployment 2 in nearly the same location as deployment 1 (within a distance of 13 ft), the depth change between the two locations was 2.7m deeper for deployment 2. Data were collected in 0.5 m depth bins. The average depth of the meter was 9.3m. The first bin after blanking is 8.19m below the water surface. The ADCP data reach to the water surface. The last bin with a full set of usable data is 1.7 m below the surface although data were collected intermittently at shallower depths during higher water periods.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Depth is measured as distance from the water surface.

Color contours of current vertical velocity, error velocity, correlation, and intensity versus depth and time. Bottom panel is average vertical (water column average) velocity versus depth and time. Velocities are in cm/s. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Correlation and intensity are in counts. Note the visible white line in the color contours at 20 May. This is the short period when the mooring was pulled after the two week deployment 1 interval.

Time history plots of water level (pressure converted to depth in meters), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees), and heading from the compass (degrees True).

Time series vector plots of the measured currents at one meter depth intervals referenced to north. In these plots, the length of the vector is equal to the speed of the current according to the speed scale (in

cm/s). The direction of the vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

For each measurement depth bin, a percent occurrence table showing the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

For each depth that a time series vector plot is provided, current roses are provided. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

3.4 Station 4 – Appendix D

Deployed at station 4 was a 1200 kHz ADCP (Teledyne RDI). The depth change between the two deployments was only 0.4m deeper for deployment 2. Data were collected in 0.5 m depth bins. The average depth of the meter was 9m. The first bin after blanking is 7.89m below the water surface. The ADCP data reach to the water surface. The last bin with a full set of usable data is 1.9 m below the surface although data were collected intermittently at shallower depths during higher water periods.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Depth is measured as distance from the water surface.

Color contours of current vertical velocity, error velocity, correlation, and intensity versus depth and time. Bottom panel is average vertical (water column average) velocity versus depth and time. Velocities are in cm/s. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Correlation and intensity are in counts. Note the visible white line in the color contours at 20 May. This is the short period when the mooring was pulled after the two week deployment 1 interval.

Time history plots of water level (pressure converted to depth in meters), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees), and heading from the compass (degrees True).

Time series vector plots of the measured currents at one meter depth intervals referenced to north. In these plots, the length of the vector is equal to the speed of the current according to the speed scale (in cm/s). The direction of the vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

For each measurement depth bin, a percent occurrence table showing the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

For each depth that a time series vector plot is provided, current roses are provided. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of

the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

3.5 CTD Profiles – Appendix E

Conductivity-temperature-depth (CTD) profiles were collected using a Hydrolab DS5 CTD during the OTS current measurements. One CTD profile was taken at the mid point of the cross channel transect line. Transect line 1 was near ADCP station 1, transect line 2 was near ADCP station 2, and transect line 3 was near ADCP station 3. All three profiles were collected approximately once an hour.

One profile is presented per page in the appendix. At the top of the page is information for the cast; date, cast ID, start time, duration, number of samples collected, and tidal stage. Cast ID refers to the sample round, line number, and time of the profile. For example R1L1_1903 is round 1 transect line 1 at time 19:03. The table lists CTD parameters for the near surface, mid, and bottom depth of the profile. The plots show the full CTD profile for each parameter versus depth along with the duration of each profile versus depth.

3.6 Over-the-Side Current Measurements – Appendix F

A Teledyne RDI 600 kHz Rio Grande ADCP was used for collecting current profiles over a 24-hour tidal survey. Four transect lines were surveyed for currents as shown in Figure 1. The cross channel transects (1 through 3) were consistently started on the east side of the waterway and ended on the west side. The along channel transect 4 always started at the south end of the waterway and ended at the north end.

Color contours of current speed versus depth and current direction versus depth along the transects. The plots for Transects 1 – 3 are oriented east (E, right) start of transect to west (W, left) end of the transect. For Transect 4 the plots are orientated south (S, left) start of transect to north (N, right) end of transect. Orientation of the transect is shown in the upper left corner of the page denoted by “Ship Track”. Distance along the transect from the start is shown on the bottom. Current speed is in cm/s and current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. The bottom panel shows the average current speed and direction for the entire profile. To provide a better visual presentation of circulation features, three current profiles (ensembles) were averaged together for one profile.

Files of the processed data are provided on the data CD. File format and units are provided in the first two lines of each data file. Bad or missing data (typically near the surface bins) are designated with 99999.

4.0 Data Discussion

4.1 Data Quality and Quantity

Current data from the four deployment sites exhibited data of high quality. This is illustrated clearly in the color contour plots of the data from the profiling meters (see sections 1 and 2 of each stations respective appendix). There were only a few instances when data quality was compromised. The first

was at Station 1 during the initial two week deployment. The transducer head for beam 1 was physically blocked by possibly a biological organism or marine debris. Data was lost for the period of 05:50 18 May to 08:40 19 May. The second and final instances occurred at Station 3 during the 4 week second deployment. Interference of the acoustic signal is seen in the upper half of the water column 20-21 May and 6-7 June. Speculation is a vessel or barge moored at the surface.

The heading, pitch, and roll sensors indicate the moorings remained fairly steady throughout the deployment. The meter for station 1 is mounted in a gimbal and shows some movement in the pitch and roll. The mounts at stations 3 and 4 were deployed on an incline during the second 4-week deployment. The meters can compensate for these effects and data quality is not impacted.

Measurements from the water level gauge (tide station) installed in the EWW tracks well with the NOAA Seattle tide station (figure 2). There is some lag time between stations as expected due to geographic locations. During low tides the freshwater lens in the EWW produces about a 1.8 in added difference in the two measurements.

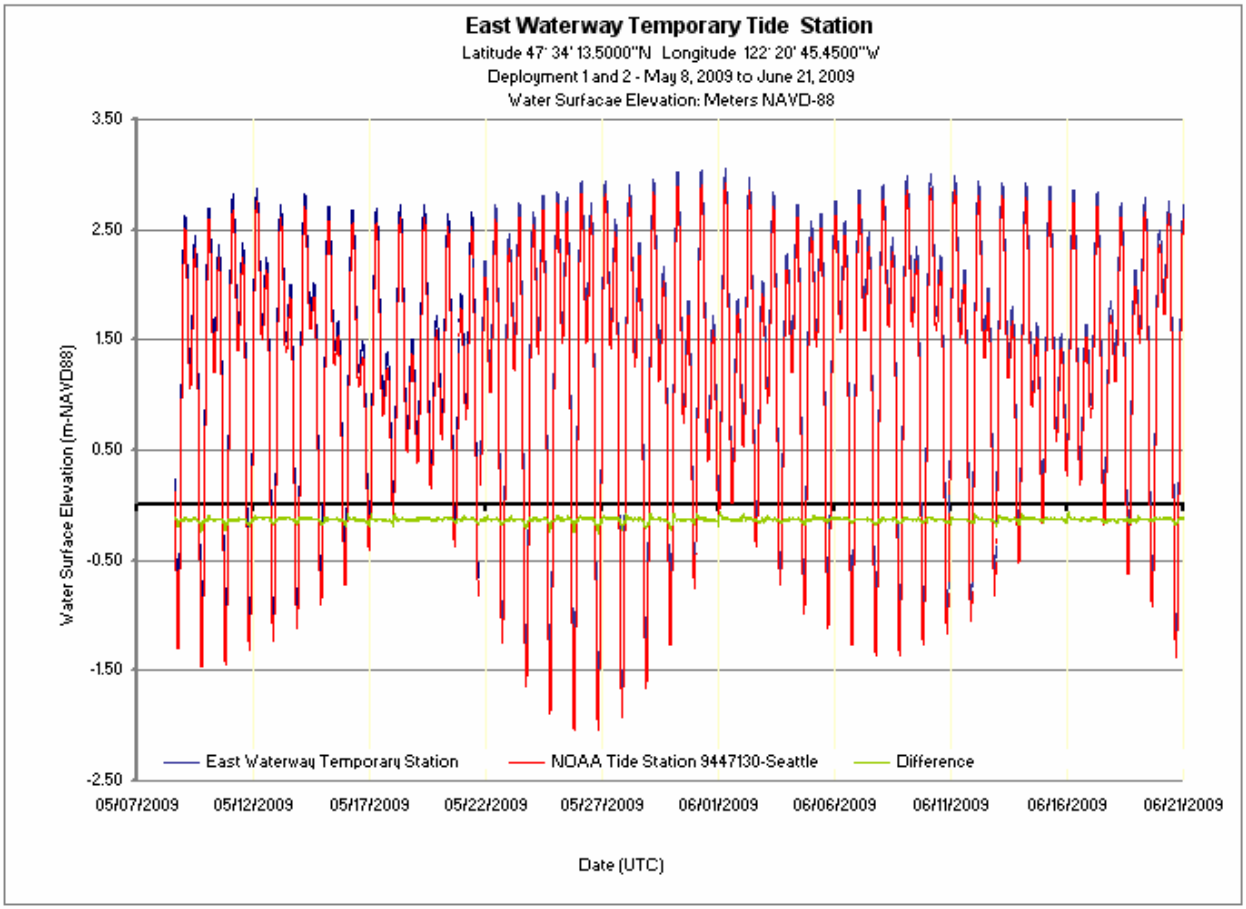

Figure 2. Comparison of tidal signal at temporary station in East Waterway and NOAA Seattle. Green line is difference between the measurements at both sites.

4.2 Data Results

Current flow is not uniform through the waterway. However, there is both a tidal and river flow evident in the measurements. The temperature signatures at the four current meter sites show a gradual increase in water temperature through the deployments. At stations 1 and 2 the temperature increase is 2°C. At stations 3 and 4 the temperature increases are approximately 2.25°C and 2.8°C, respectively. The temperature record shows a tidal signal as well. Generally on the rising tide the water temperature gets warmer. The tidal signature is not as pronounced at station 1 and mostly seen in the last half of the record. At stations 2, 3, and 4 the tidal signal is seen throughout the temperature record.

4.2.1 Currents at ADCP sites

At the most northern site (station 1) at the mouth of the EWW, the currents rarely exceed half a knot (25.7 cm/s). The maximum current speed recorded was 37.6 cm/s at 3.8m on 12 June. However, over 90% of the record has speeds less than 12 cm/s. Average speeds ranged from 4.67 cm/s to 8.47 cm/s (Table 3). The percent occurrence products (tables and roses) illustrate the overall flow patterns. In the near surface layer (0.8 – 4.8m) water flow tends toward the north (out into Elliott Bay). Near mid depth (7.8 – 11.8m) flow is more southerly. In the very near bottom layer (15.8 – 16.8m) flow again tends to flow northward.

Table 3. Record statistics for currents at Station 1.

Depth	Data Pts	Avg East	Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
0.8	2550	0.63	1.48	8.47	31.31	183	0.1	62	1.60	23
1.8	4267	-0.14	2.49	8.08	32.13	359	0.1	358	2.50	357
2.8	5592	-0.06	2.25	8.02	36.07	84	0.0	0	2.25	358
3.8	6383	-0.49	1.48	7.48	37.64	54	0.0	0	1.56	342
4.8	6654	-1.09	0.93	6.89	34.44	44	0.0	0	1.43	311
5.8	6658	-1.34	0.15	6.49	31.84	321	0.0	0	1.35	277
6.8	6658	-1.45	-0.46	6.09	33.27	311	0.0	0	1.52	252
7.8	6670	-1.20	-0.94	5.60	28.03	317	0.0	0	1.53	232
8.8	6681	-0.89	-1.26	5.13	22.19	52	0.0	0	1.54	215
9.8	6691	-0.72	-1.27	4.84	18.89	60	0.0	0	1.46	210
10.8	6694	-0.60	-1.12	4.70	18.82	105	0.0	0	1.27	208
11.8	6695	-0.55	-0.95	4.67	19.77	66	0.0	0	1.09	210
12.8	6697	-0.55	-0.60	4.71	20.96	328	0.0	0	0.82	223
13.8	6697	-0.46	-0.33	4.90	24.94	191	0.1	358	0.56	234
14.8	6699	-0.42	0.04	5.00	23.58	190	0.0	0	0.42	275
15.8	6698	-0.40	0.51	5.12	25.81	195	0.0	0	0.65	322
16.8	6412	-1.78	0.26	6.25	26.84	200	0.1	17	1.80	278

At the mid waterway station (station 2) currents are still primarily below half a knot. The maximum current speed recorded was 43.2 cm/s at 1.9m depth. Average speeds were higher than station 1 ranging from 8.14 – 12.20 cm/s (Table 4). At the very near surface bin (0.9m) 86% of the record is below 20cm/s, and for all other depths over 90% of the record is below 20 cm/s. As was seen at station 1, station 2 also exhibits a layered flow where the near surface bins tend to flow north and the lower depths toward the south. However, water flow at station 2 is not as well defined in these directions. We were uncertain if there was an influence from Slip 27 to the east or the meter was not performing properly. Beginning with deployment 3 a new meter was deployed at this site.

Table 4. Record statistics for currents at Station 2.

Depth	Data Pts	Avg East	Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
0.9	3294	-0.04	1.55	12.20	36.7	264	0.0	0	1.55	359
1.9	5058	-0.05	1.94	10.80	43.2	190	0.0	0	1.95	358
2.9	5960	0.10	0.88	10.09	39.1	169	0.0	0	0.89	6
3.9	6616	0.24	0.39	9.76	38.6	164	0.0	0	0.46	32
4.9	6872	0.38	-0.16	9.30	33.4	201	0.1	0	0.41	112
5.9	6883	0.27	-0.75	8.91	37.3	144	0.2	207	0.80	160
6.9	6884	0.30	-1.11	8.67	32.6	155	0.1	180	1.15	165
7.9	6882	0.11	-1.12	8.46	31.2	177	0.1	0	1.12	175
8.9	6886	0.25	-1.02	8.35	30.6	241	0.0	0	1.05	166
9.9	6886	0.12	-1.19	8.24	29.9	89	0.0	0	1.20	174
10.9	6887	0.15	-0.85	8.16	30.1	159	0.0	0	0.87	170
11.9	6888	0.08	-0.59	8.14	28.9	167	0.0	0	0.59	172
12.9	6890	0.06	-0.46	8.18	31.9	62	0.1	90	0.47	172
13.9	6891	-0.12	-0.08	8.26	32.5	352	0.0	0	0.14	236
14.9	6891	-0.13	0.04	8.37	29.8	344	0.0	0	0.13	286
15.9	6891	-0.16	0.24	8.38	30.3	351	0.0	0	0.29	325
16.9	6891	-0.48	0.44	8.54	27.9	299	0.0	0	0.65	313

At the southern site (station 3) the flow pattern is NNE and SSW aligning with the bend in the waterway. The maximum current speed was 46.0 cm/s near the surface at 1.19m (Table 5). Average currents were 2.15 – 11.84 cm/s. This location shows a definite two-layer flow. The upper half of the water column flows northward. The higher current speeds are also seen in this layer although over 90% of the record is less than half a knot. In the lower part of the water column the flow is predominantly to the south. The current speed drops off significantly in the lower depths where over 95% of the record is below 8 cm/s (below 5.5m it approaches 98% of the record).

Table 5. Record statistics for currents at Station 3.

Depth	Data Pts	Avg East	Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
-0.81	586	3.04	9.50	10.91	31.8	354	0.7	99	9.97	18
-0.31	1431	3.79	9.14	11.84	34.3	9	0.3	359	9.89	23
0.19	2517	2.86	7.32	11.29	38.7	5	0.1	62	7.86	21
0.69	3430	2.58	5.86	11.15	40.0	27	0.1	152	6.40	24
1.19	4118	1.85	4.49	10.52	46.0	25	0.1	152	4.86	22
1.69	4803	1.33	3.44	9.89	41.7	26	0.1	152	3.69	21
2.19	5447	0.96	2.63	9.17	40.3	26	0.0	0	2.81	20
2.69	5988	0.71	1.85	7.99	39.1	25	0.1	107	1.98	21
3.19	6314	0.44	0.80	6.44	39.5	26	0.0	0	0.91	29
3.69	6558	0.10	-0.16	4.87	35.2	19	0.0	0	0.19	149
4.19	6684	-0.23	-0.87	3.67	26.3	24	0.0	0	0.90	195
4.69	6854	-0.44	-1.20	3.04	23.2	233	0.0	0	1.28	200
5.19	6887	-0.68	-1.21	2.62	21.4	236	0.0	0	1.39	209
5.69	6891	-0.75	-1.13	2.41	19.3	35	0.0	0	1.36	213
6.19	6891	-0.74	-0.99	2.32	17.1	32	0.0	0	1.23	217
6.69	6891	-0.71	-0.83	2.24	17.3	23	0.0	0	1.10	221
7.19	6891	-0.63	-0.66	2.17	19.4	35	0.0	0	0.91	224
7.69	6891	-0.54	-0.47	2.15	20.4	26	0.0	0	0.71	229
8.19	6891	-0.39	-0.27	2.18	21.3	29	0.0	0	0.47	235

The junction site (station 4) is the most energetic of all four measurement sites. The maximum speed was 54.9 cm/s at 2.89m, the only site where currents reached above 1 knot (Table 6). The average speeds range from 6.37 – 15.78 cm/s. Flow is directed north and south and although the flow is very tidally driven, there is a net three-layer flow. In the upper half of the water column (above 4m) net flow is northward and maximum currents are to the north. In the depth range of 4 – 6.5m the net flow is southward and the maximum currents are directed south. In the near bottom depths (below 6.5m) the net flow is northward but the maximum currents are all to the south.

Table 6. Record statistics for currents at Station 4.

Depth	Data Pts	Avg East	Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
-0.11	732	2.98	13.78	14.75	45.7	9	0.3	152	14.09	12
0.39	1854	1.80	13.86	15.57	46.9	360	0.2	171	13.97	7
0.89	3215	1.63	13.00	15.78	49.4	360	0.2	314	13.10	7
1.39	4088	0.77	10.16	14.91	45.6	14	0.0	0	10.19	4
1.89	4786	0.26	6.85	14.65	48.9	1	0.0	0	6.86	2
2.39	5390	0.03	4.90	14.73	52.9	10	0.0	0	4.90	0
2.89	5861	-1.10	2.73	14.81	54.9	9	0.1	152	2.94	338
3.39	6270	-1.25	1.35	14.95	52.1	7	0.2	171	1.84	317
3.89	6612	-1.23	0.42	14.98	49.5	6	0.1	107	1.30	289
4.39	6848	-0.87	-0.50	14.12	48.4	192	0.0	0	1.00	240
4.89	6890	-0.64	-0.98	12.73	49.8	190	0.0	0	1.17	213
5.39	6894	-0.42	-1.27	10.76	51.3	190	0.0	0	1.34	199
5.89	6897	-0.08	-0.86	8.78	50.6	186	0.0	0	0.86	185
6.39	6897	0.11	-0.40	7.71	49.0	188	0.0	0	0.42	164
6.89	6897	0.24	0.14	7.07	47.4	190	0.0	0	0.28	61
7.39	6898	0.49	0.74	6.67	42.9	188	0.0	0	0.89	33
7.89	6897	0.44	1.18	6.37	39.4	185	0.0	0	1.26	20

4.2.2 CTD Casts

The CTD casts show a thin freshwater lens in the very near surface (< 3m) waters and more saline water in the rest of the water column. Dissolved oxygen through the water column at all three sites was above 8 mg/L. Water temperature was slightly warmer within the thin freshwater lens at the surface and cooled with depth but generally only by a difference of 0.5°C. The pH remained constant through the water column and at all three stations with an average of 7.7.

4.2.3 Over-the-Side Currents

The general trend for the OTS current survey is that the flow is weak and variable. Current speeds were generally below 12 cm/s. However, there are some general trends in the weak currents. Near the beginning of a tidal change the flow direction is more evident in the near surface waters. For example, during a flood tide (see transects on 5/14/09 during 11:50 through 13:59) the 5-7m show a southerly flow while the water below these depths is still moving northward. During the ebb tide (see transects on 5/14/09 during 16:31 through 18:22) the northward flow is at the surface for transects 2 and 3. At transect 1 and the northern portion of transect 4 (along channel) the surface waters are still flowing southward while the lower water column (transect 1) and southern waters (transect 4) are flowing northward.

EVANS-HAMILTON, INC.

DUWAMISH RIVER – EAST WATERWAY

OCEANOGRAPHIC DATA COLLECTION

DEPLOYMENT 3 DATA REPORT

SEPTEMBER 2009

PREPARED FOR

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EHI PROJECT NO. S5916

DUWAMISH RIVER – EAST WATERWAY OCEANOGRAPHIC DATA COLLECTION DEPLOYMENT 3 DATA REPORT CONTENTS

DUWAMISH RIVER – EAST WATERWAY

CONTENTS CONTINUED

FIGURES

APPENDICES

1.0 INTRODUCTION

Evans-Hamilton, Inc. (EHI) conducted field measurements in support of the Anchor QEA, LLC project East Waterway Supplemental Remedial Investigation and Feasibility Study for the Port of Seattle. The field measurements consisted of deploying four current measurement systems, installing one water level gauge, and conducting real-time current profiles in the East Waterway (EWW) of the Duwamish River in Seattle, WA. Data Report 1 reviewed the results from deployments 1 and 2 (two-week and one-month periods, respectively) of the bottom mounted current meters, water level gauge, real-time current profiles, and CTD casts. This report summarizes the deployment 3 data for the bottom mounted current meters and water level gauge during the one-month period 24 June – 28 July, 2009. Station locations for the meters are shown in Figure 1.

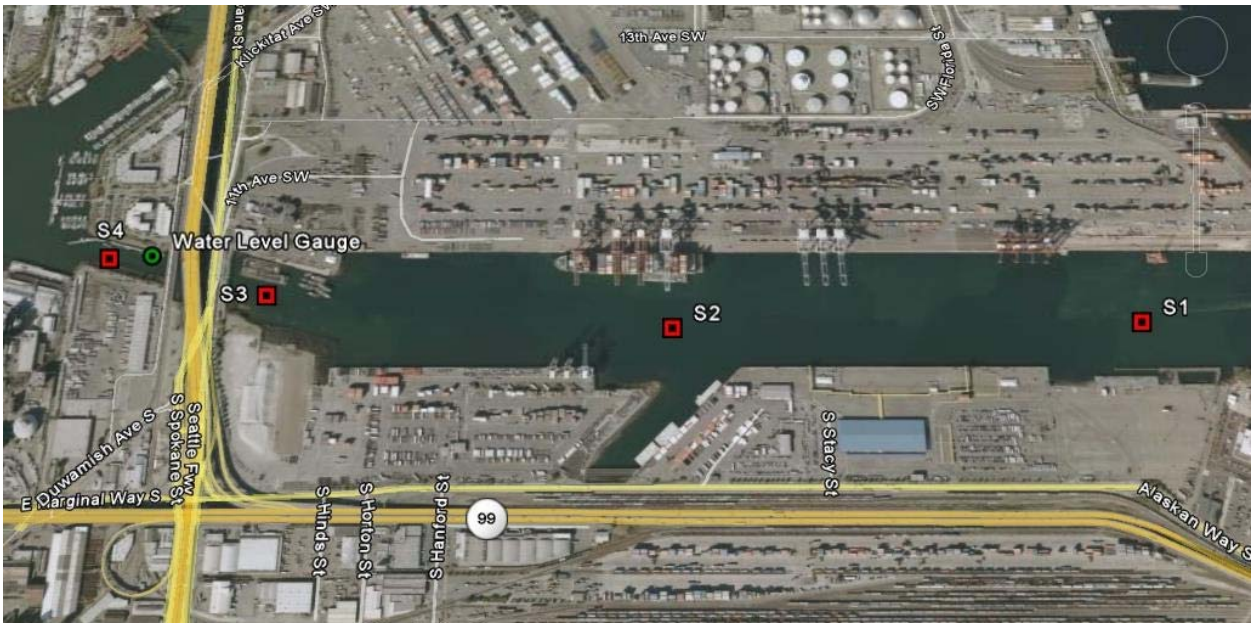

Figure 1. Current meter (red squares) and water level gauge (green circle) station locations for deployment 3.

2.0 EQUIPMENT AND FIELD PROCEDURES

The four current meter mounts were retrieved, serviced, and redeployed on 28 July 2009. During the mount service, the systems were checked and bio-fouling cleaned if required. The current meters were downloaded, data and operation evaluated, and then set-up for Deployment 4. The tide station data was downloaded on 27 July 2009 the day before the service trip for the current meters.

Review of the data in the field showed all instruments operating as programmed. Low current velocities of less than 15 cm/s (approximately a quarter knot) were observed the majority of the time at sites 1, 2, and 3. Station 4 showed the highest currents as was observed during the previous deployments.

Prior to redeployment, all current meters were stepped through the check out procedure and a final verification of settings. No changes were made to instrument sampling settings other than time synchronization and start times. All bottom mounts were redeployed using the same method as the previous deployments. Table 2 lists the station locations for deployments 3 and 4. The moorings are scheduled for final retrieval in one month from the deployment date of 28 July 2009.

Table 1. Deployment 3 and 4 station locations.

Site	**Latitude** (Deg. Min. Sec.)	**Longitude** (Deg. Min. Sec.)	**Deployment Date** (UTC)	**Recovery Date** (UTC)	**Water Depth** (Meters, at Deployment)
Deployment 3					
Station 1	47° 35’ 13.8852”	122° 20’ 39.1111”	06/24/2009	07/28/2009	18.5
Station 2	47° 34’ 45.4986”	122° 20’ 38.5722”	06/24/2009	07/28/2009	15.2
Station 3	47° 34’ 20.8032”	122° 20’ 41.6560”	06/24/2009	07/28/2009	7.6
Station 4	47° 34’ 10.8940”	122° 20’ 45.1922”	06/24/2009	07/28/2009	7.6
Tide Station	47° 34' 13.5000"	122° 20' 45.4500"	06/26/2009	07/27/2009	---
Deployment 4					
Station 1	47° 35’ 14.0053”	122° 20’ 39.5096”	07/28/2009		15.0
Station 2	47° 34’ 45.3177”	122° 20’ 38.8685”	07/28/2009		15.2
Station 3	47° 34’ 20.3944”	122° 20’ 41.6036”	07/28/2009		7.0
Station 4	47° 34’ 10.8940”	122° 20’ 45.1922”	07/28/2009		7.1
Tide Station	47° 34' 13.5000"	122° 20' 45.4500"	07/27/2009		---

3.0 DATA PROCESSING AND ANALYSIS

The data has undergone processing using EHI standard routines. Data plots and tables have been generated as well as text files of the data. The organization of the data products within the appendices, along with notes concerning each type of data product, is provided below. All times are referenced to UTC.

Text files of the processed data are available via the EHI ftp site. File format and units are provided at the start of each data file. Bad or missing data (typically near the surface bins) are designated with 999.9.

3.1 Station 1 – Appendix A

Deployed at station 1 was a 600 kHz AWAC (Nortek). The mount was moved 181 ft east for the second deployment placing it 1.2m deeper in depth compared to deployment 1. Data were collected in 1 m depth bins. The average depth of the meter was 18.5m. The first bin after blanking is 16.9m below the water surface. The AWAC data reach to the water surface. The last bin with a full set of usable data is 2.9m below the surface although data were collected intermittently at shallower depths during higher water periods.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Conversion of cm/s to feet/s: 30.48 cm/s = 1 ft/s.

Color contours of data quality parameters for vertical velocity and for each beam of the transducer heads of signal amplitude versus depth and time. Bottom graph is time history plot of average vertical velocity (cm/s) through the water column. Velocities are in cm/s. Amplitude is in counts.

Time history plots of water level (pressure sensor in m), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees True), and heading from the compass (degrees).

Time series vector plots of the measured currents at selected depths referenced to north. The length of the vector is equal to the speed of the current according to the speed scale (in cm/s). The direction of the vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

Percent occurrence tables for each measured depth bin. Table shows the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

Current roses of percent occurrence of current speed versus direction for each depth shown in the time series vector plots. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

3.2 Station 2 – Appendix B

Deployed at station 2 beginning with deployment 3 was a 600 kHz ADCP (Teledyne RDI). Data were collected in 1 m depth bins. The average depth of the meter was 17.4m. The first bin after blanking is 15.3m below the water surface. The ADCP data reach to the water surface. The last bin with a full set of usable data is 2.3m below the surface although data were collected intermittently at shallower depths during higher water periods.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Conversion of cm/s to feet/s: 30.48 cm/s = 1 ft/s.

Color contours of current vertical velocity, error velocity, correlation, and intensity versus depth and time. Bottom panel is average vertical (water column average) velocity versus depth and time. Velocities are in cm/s. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Correlation and intensity are in counts.

Time history plots of water level (pressure sensor in m), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees True), and heading from the compass (degrees).

Time series vector plots of the measured currents at selected depths referenced to north. The length of the vector is equal to the speed of the current according to the speed scale (in cm/s). The direction of the vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

Percent occurrence tables for each measured depth bin. Table shows the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

Current roses of percent occurrence of current speed versus direction for each depth shown in the time series vector plots. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

3.3 Station 3 – Appendix C

Deployed at station 3 was a 1200 kHz ADCP (Teledyne RDI). Data were collected in 0.5 m depth bins. The average depth of the meter was 9.8m. The first bin after blanking is 8.8m below the water surface. The ADCP data reach to the water surface. The last bin with a full set of usable data is 1.8 m below the surface although data were collected intermittently at shallower depths during higher water periods.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Depth is measured as distance from the water surface.

Color contours of current vertical velocity, error velocity, correlation, and intensity versus depth and time. Bottom panel is average vertical (water column average) velocity versus depth and time. Velocities are in cm/s. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Correlation and intensity are in counts.

Time history plots of water level (pressure converted to depth in meters), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees), and heading from the compass (degrees True).

Time series vector plots of the measured currents at one meter depth intervals referenced to north. In these plots, the length of the vector is equal to the speed of the current according to the speed scale (in cm/s). The direction of the vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

For each measurement depth bin, a percent occurrence table showing the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

For each depth that a time series vector plot is provided, current roses are provided. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

3.4 Station 4 – Appendix D

Deployed at station 4 was a 1200 kHz ADCP (Teledyne RDI). Data were collected in 0.5 m depth bins. The average depth of the meter was 9.9m. The first bin after blanking is 8.9m below the water surface. The ADCP data reach to the water surface. The last bin with a full set of usable data is 1.4 m below the surface although data were collected intermittently at shallower depths during higher water periods.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Depth is measured as distance from the water surface.

Color contours of current vertical velocity, error velocity, correlation, and intensity versus depth and time. Bottom panel is average vertical (water column average) velocity versus depth and time. Velocities are in cm/s. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Correlation and intensity are in counts.

Time history plots of water level (pressure converted to depth in meters), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees), and heading from the compass (degrees True).

Time series vector plots of the measured currents at one meter depth intervals referenced to north. In these plots, the length of the vector is equal to the speed of the current according to the speed scale (in cm/s). The direction of the vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

For each measurement depth bin, a percent occurrence table showing the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

For each depth that a time series vector plot is provided, current roses are provided. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

4.0 DATA DISCUSSION

4.1 Data Quality and Quantity

Current data from the four deployment sites exhibited data of high quality. This is illustrated clearly in the color contour plots of the data from the profiling meters (see sections 1 and 2 of each stations respective appendix). Replacement of the meter at station 2 appears to have improved the quality of the measured current direction.

The heading, pitch, and roll sensors indicate the moorings remained fairly steady throughout the deployment. The meter for station 1 is mounted in a gimbal and shows some movement in the pitch and

roll. The meter can compensate for these effects and data quality is not impacted. However, the field crew added additional weights for deployment 4 to reduce rocking during tidal changes and ship wakes.

Measurements from the water level gauge (tide station) installed in the EWW tracks well with the NOAA Seattle tide station (figure 2). There is some lag time between stations as expected due to geographic locations.

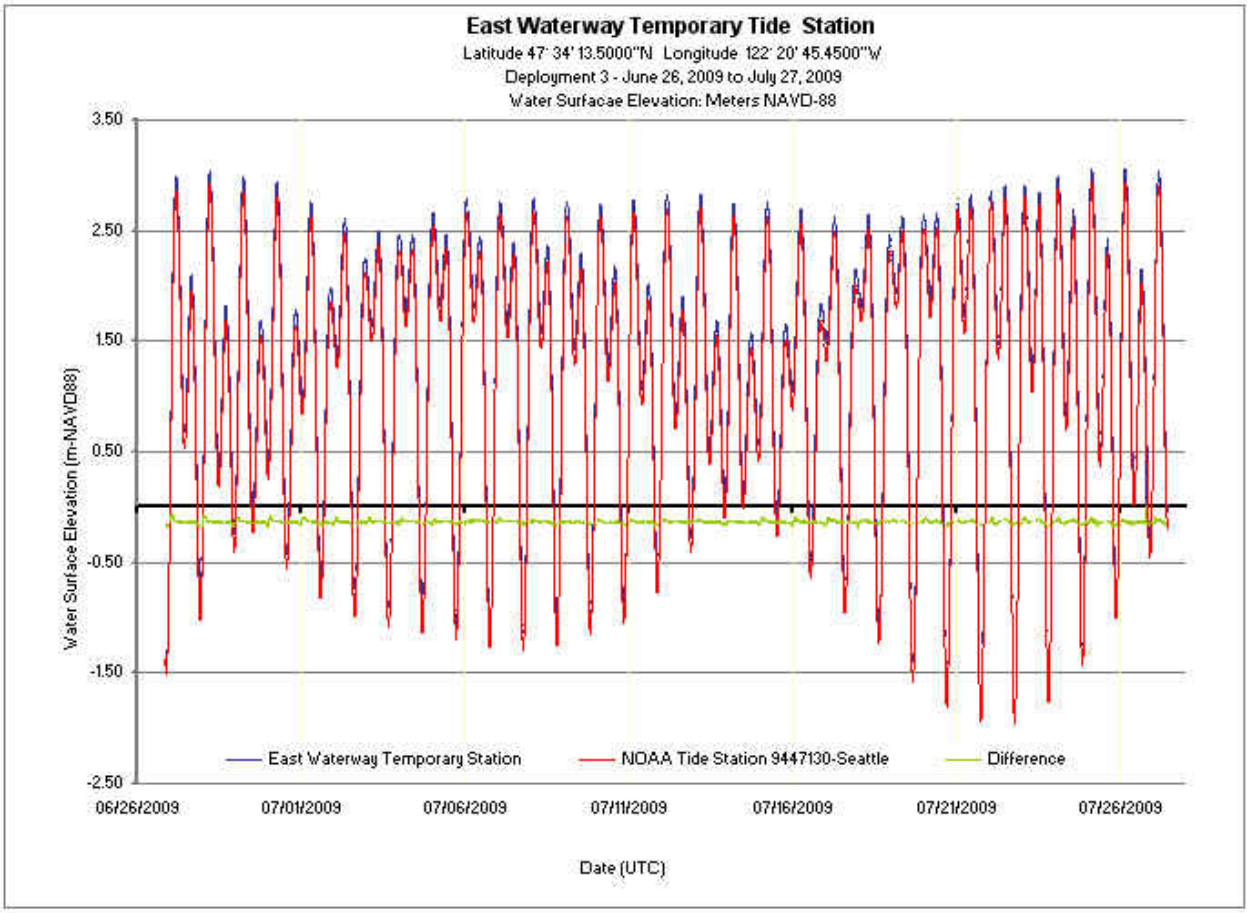

Figure 2. Comparison of tidal signal at temporary station in East Waterway and NOAA Seattle. Green line is difference between the measurements at both sites.

4.2 Data Results

As was evident for the first two deployments, current flow is not uniform through the waterway. Also evident is both a tidal and river flow in the measurements. The temperature signatures at the four current meter sites show a gradual increase in water temperature through the deployments, a continuation observed during the first two deployments. At stations 1 and 2 the temperature increase is approximately 1.5°C. At stations 3 and 4 the temperature increases are approximately 1°C and 2°C, respectively. The temperature record shows a tidal signal as well, generally becoming more pronounced moving up-river

(intermittent at station 1 and seen in most of the record at station 4). In addition, there is another feature seen in the temperature record. There are several pulses of warmer water seen in the records that last from 1 to 3 days. The first occurs June 26 and the second occurs 7-9 July. A possible third occurrence is 21-24 July. During these periods the water temperature increases about 0.5°C and then drops back down. The signal is most evident in the record for station 4 and decreases in intensity moving toward the mouth of the waterway at station 1 indicating the possible influence of the river.

4.2.1 Currents at ADCP sites

At station 1 at the mouth of the EWW, the currents remain below 12 cm/s over 90% of the time throughout the water column. A trend seen in the first deployments. The maximum current speed recorded was 39.74 cm/s at 5.9m on 22 July. Average speeds ranged from 4.96 cm/s to 6.57 cm/s (Table 2). The percent occurrence products (tables and roses) illustrate the overall flow patterns. In the near surface layer (0 – 4m) water flow tends toward the north (out into Elliott Bay). Below this depth flow is toward the south. Maximum current speeds are generally all northward.

Table 2. Record statistics for currents at Station 1. All speeds are cm/s.

Depth	Data Pts	Speed Avg East	Speed Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
0.9	1732	2.02	3.03	6.57	24.39	55.9	0.1	17.1	3.64	33.7
1.9	3230	2.04	1.20	6.42	27.62	50.7	0	0	2.37	59.5
2.9	4090	1.67	0.07	6.31	22.54	38.4	0	0	1.67	87.6
3.9	4681	1.68	-0.57	6.26	23.68	102.2	0	0	1.78	108.8
4.9	4850	1.49	-1.06	5.93	36.90	274.4	0	0	1.83	125.3
5.9	4854	1.09	-1.60	5.55	39.74	279.5	0	0	1.93	145.8
6.9	4851	0.71	-1.90	5.43	34.31	282.4	0	0	2.03	159.6
7.9	4835	0.55	-2.05	5.38	33.44	298.3	0	0	2.12	165.0
8.9	4860	0.49	-2.29	5.21	36.49	295.4	0	0	2.34	167.9
9.9	4860	0.56	-2.42	5.16	35.10	286.9	0.1	17.1	2.49	167.0
10.9	4860	0.44	-2.44	5.09	27.74	281.3	0	0	2.48	169.7
11.9	4860	0.38	-2.34	5.03	30.25	283.6	0	0	2.37	170.9
12.9	4859	0.41	-2.21	5.01	30.62	289.3	0	0	2.25	169.6
13.9	4859	0.44	-2.09	5.05	31.60	287.6	0	0	2.13	168.1
14.9	4860	0.48	-1.97	5.07	27.79	295.3	0	0	2.03	166.2
15.9	4859	0.52	-1.72	4.96	24.43	292.9	0	0	1.80	163.2
16.9	4858	-0.12	-0.88	5.90	29.40	303.5	0	0	0.89	187.4

At station 2, midway in the waterway, currents are still primarily below half a knot. The maximum current speed recorded was 46.8 cm/s at 4.3m depth. Average speeds ranged from 2.31 – 11.98 cm/s (Table 3), lower than the first deployments. In the upper 2/3 of the water column over 80% of the record is below 20cm/s. A sharp decrease in current speed is evident in the lower 1/3 of the water column (9.3 m and deeper) where 98% of the record is below 8 cm/s. There appears to be an influence from Slip 27 in the upper depth ranges. The net flow is to the east. At depths 9.3m and deeper, the net flows are toward the south and then toward the north at the very near bottom depths.

Table 3. Record statistics for currents at Station 2.

Depth	Data Pts	Avg East	Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
0.28	1094	3.01	1.48	8.55	31.5	1.9	0.2	287.1	3.35	63.9
1.28	2859	3.84	2.92	9.08	34.8	6.2	0.2	80.5	4.82	52.7
2.28	3817	5.55	2.58	9.73	46.1	126.8	0.1	287.1	6.12	65.1
3.28	4435	7.33	1.44	11.17	45.3	131.1	0.2	313.6	7.47	78.9
4.28	4653	8.38	-0.64	11.98	46.8	123.5	0	0	8.40	94.3
5.28	4784	7.38	-2.34	10.83	46.6	128.8	0.1	197.1	7.74	107.6
6.28	4852	5.17	-2.87	7.87	36.6	113.9	0	0	5.91	119.0
7.28	4868	2.93	-2.33	5.34	37.0	145.3	0.1	332	3.74	128.5
8.28	4872	1.10	-1.33	3.30	29.4	125.4	0	0	1.72	140.4
9.28	4872	0.14	-0.62	2.42	26.4	118.1	0	0	0.63	166.9
10.28	4875	-0.19	-0.30	2.31	17.7	204.9	0	0	0.36	212.9
11.28	4877	-0.27	-0.16	2.32	22.5	198.6	0	0	0.32	239.4
12.28	4877	-0.26	-0.02	2.37	18.2	208.2	0	0	0.26	265.4
13.28	4878	-0.15	0.17	2.43	18.0	332.3	0	0	0.23	317.3
14.28	4878	-0.11	0.31	2.51	18.4	331.2	0	0	0.33	341.4
15.28	4877	-0.08	0.39	2.68	19.6	326.3	0	0	0.40	348.9

At station 3 the flow pattern is similar to earlier deployments, NNE and SSW aligning with the bend in the waterway. The maximum current speed was 33.4 cm/s at 2.79m (Table 4), a 13 cm/s decrease from earlier measurements. Average currents were 2.20 – 10.51 cm/s consistent with previous results. This location shows a definite two-layer flow. The upper half of the water column flows northward. The higher current speeds are also seen in this layer although over 94% of the record is less than half a knot. In the lower part of the water column the flow is predominantly to the south. The current speed drops off significantly in the lower depths where over 93% of the record is below 8 cm/s.

Table 4. Record statistics for currents at Station 3.

Depth	Data Pts	Avg East	Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
0.29	1046	1.43	5.50	10.51	28.7	29.0	0.3	268.6	5.68	14.6
0.79	2041	1.41	4.02	10.23	29.5	19.6	0.2	287.1	4.26	19.3
1.29	2659	1.28	2.66	10.11	32.8	30.3	0.1	107.1	2.95	25.7
1.79	3288	1.03	2.14	9.68	31.6	7.4	0.2	287.1	2.38	25.6
2.29	3796	0.79	2.02	9.35	31.4	15.9	0.1	17.1	2.17	21.3
2.79	4209	0.75	1.69	8.74	33.4	342.8	0	0	1.85	23.8
3.29	4521	0.78	1.28	7.82	30.7	34.4	0	0	1.50	31.2
3.79	4789	0.45	0.73	6.39	29.7	36.8	0	0	0.86	31.6
4.29	4852	0.22	-0.16	4.92	24.6	45.1	0	0	0.27	126.0
4.79	4852	-0.08	-0.79	3.91	22.9	34.9	0	0	0.79	185.9
5.29	4852	-0.36	-1.14	3.18	19.4	32.9	0	0	1.20	197.4
5.79	4853	-0.63	-1.34	2.72	16.3	42.5	0	0	1.48	205.3
6.29	4853	-0.85	-1.33	2.47	14.6	92.3	0	0	1.57	212.6
6.79	4852	-0.90	-1.25	2.38	15.3	204.1	0	0	1.54	215.6
7.29	4853	-0.86	-1.14	2.35	13.2	232.7	0	0	1.43	217.1
7.79	4853	-0.76	-0.99	2.30	14.4	90.1	0	0	1.25	217.5
8.29	4853	-0.65	-0.80	2.24	13.9	76.2	0	0	1.03	218.9
8.79	4853	-0.50	-0.60	2.20	14.0	237.5	0	0	0.78	219.8

The junction site (station 4) continues to be the most energetic of all four measurement sites. The maximum speed was 64.9 cm/s at both 6.39m and 6.89m (Table 5), much deeper than previously seen. This is the only site where currents reached above 1 knot. The average speeds range from 9.00 – 15.76 cm/s. Flow is directed north and south and although the flow is very tidally driven, there is a net two-layer flow. In the upper half of the water column (above 3.5m) net flow is northward and maximum currents are to the north. Below the 4m depth range the net flow is southward and the maximum currents are directed south.

Table 5. Record statistics for currents at Station 4.

Depth	Data Pts	Avg East	Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
0.39	1519	2.52	11.14	14.48	37.8	19.3	0.1	242.1	11.42	12.7
0.89	2424	1.41	9.11	14.29	35.5	2.8	0.1	17.1	9.22	8.8
1.39	3109	0.70	7.87	14.35	37.9	354.4	0.1	287.1	7.90	5.1
1.89	3553	0.02	6.14	14.50	44.0	357.9	0.1	152.1	6.14	0.2
2.39	3944	-0.44	4.47	14.84	45.0	355.3	0.1	197.1	4.49	354.4
2.89	4319	-0.73	3.04	15.28	45.0	344.8	0	0	3.12	346.4
3.39	4613	-0.60	1.90	15.65	44.0	343.7	0	0	1.99	342.6
3.89	4787	-0.90	0.25	15.76	45.2	186.5	0.1	332	0.94	285.6
4.39	4851	-1.01	-1.73	15.49	50.7	185.8	0.1	62	2.00	210.2
4.89	4852	-1.05	-2.75	14.92	56.4	186.2	0	0	2.95	200.9
5.39	4852	-0.93	-3.25	14.15	60.7	187.3	0	0	3.38	196.0
5.89	4852	-0.78	-3.28	13.25	63.6	191.6	0.1	152.1	3.37	193.3
6.39	4851	-0.58	-3.03	12.34	64.9	191.9	0.1	242.1	3.09	190.8
6.89	4851	-0.49	-2.63	11.58	64.9	192.7	0	0	2.68	190.5
7.39	4851	-0.35	-2.11	10.88	61.9	191.6	0.1	332	2.14	189.5
7.89	4851	-0.18	-1.52	10.24	59.3	192.9	0	0	1.54	186.7
8.39	4851	-0.02	-0.87	9.66	55.5	192.8	0	0	0.87	181.5
8.89	4851	0.09	-0.25	9.00	50.5	192.2	0	0	0.27	160.9

EVANS-HAMILTON, INC.

DUWAMISH RIVER – EAST WATERWAY

OCEANOGRAPHIC DATA COLLECTION

DEPLOYMENT 4 DATA REPORT

OCTOBER 2009

PREPARED FOR

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EHI PROJECT NO. S5916

DUWAMISH RIVER – EAST WATERWAY OCEANOGRAPHIC DATA COLLECTION DEPLOYMENT 4 DATA REPORT CONTENTS

DUWAMISH RIVER – EAST WATERWAY

CONTENTS CONTINUED

FIGURES

APPENDICES

1.0 INTRODUCTION

Evans-Hamilton, Inc. (EHI) conducted field measurements in support of the Anchor QEA, LLC project East Waterway Supplemental Remedial Investigation and Feasibility Study for the Port of Seattle. The field measurements consisted of deploying four current measurement systems, installing one water level gauge, and conducting real-time current profiles in the East Waterway (EWW) of the Duwamish River in Seattle, WA. Data Report 1 reviewed the results from deployments 1 and 2 (two-week and one-month periods, respectively) of the bottom mounted current meters, water level gauge, real-time current profiles, and CTD casts. Data Report 2 summarized the deployment 3 data for the bottom mounted current meters and water level gauge during the one-month period 24 June – 28 July, 2009. This final data report summarizes deployment 4 data for the 4 bottom mounted current meters and the water level gauge during the period 28 July – 18 August, 2009. Station locations for the meters are shown in Figure 1.

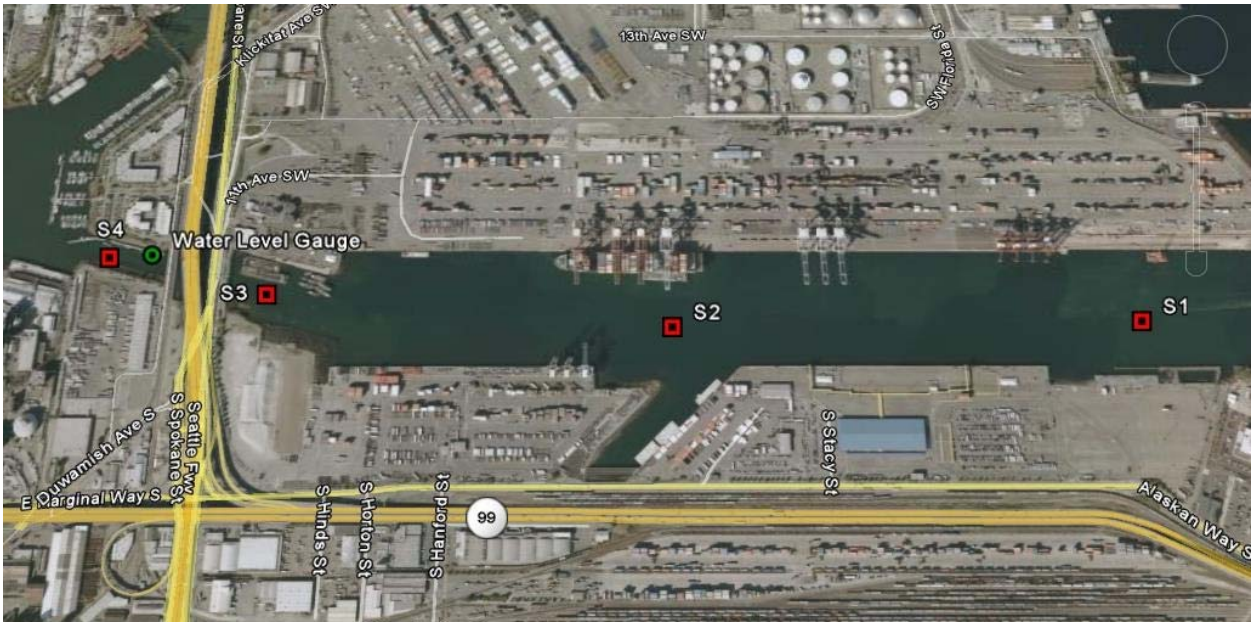

Figure 1. Current meter (red squares) and water level gauge (green circle) station locations for deployment 3.

2.0 EQUIPMENT AND FIELD PROCEDURES

The four current meter mounts were retrieved on 18 August 2009. The tide station data was downloaded on 18 August 2009 and then dismantled and removed from the site.

Review of the data in the field showed all instruments operated as programmed. Similar to the earlier deployments, low current velocities of less than 15 cm/s (approximately a quarter knot) were observed much of the time at sites 1, 2, and 3 and site 4 showed the highest currents.

Table 1 lists the station locations for deployment 4. This was the final deployment for the moorings and water level gauge.

Table 1. Deployment 4 station locations.

Site	Latitude (Deg. Min. Sec.)	Longitude (Deg. Min. Sec.)	Deployment Date (UTC)	Recovery Date (UTC)	Water Depth (Meters, at Deployment)
Deployment 4					
Station 1	47° 35' 14.0053"	122° 20' 39.5096"	07/28/2009	08/18/2009	15.0
Station 2	47° 34' 45.3177"	122° 20' 38.8685"	07/28/2009	08/18/2009	15.2
Station 3	47° 34' 20.3944"	122° 20' 41.6036"	07/28/2009	08/18/2009	7.0
Station 4	47° 34' 10.8940"	122° 20' 45.1922"	07/28/2009	08/18/2009	7.1
Tide Station	47° 34' 13.5000"	122° 20' 45.4500"	07/27/2009	08/18/2009	---

3.0 DATA PROCESSING AND ANALYSIS

The data has undergone processing using EHI standard routines. Data plots and tables have been generated as well as text files of the data. The organization of the data products within the appendices, along with notes concerning each type of data product, is provided below. All times are referenced to UTC.

Text files of the processed data are available via the EHI ftp site. File format and units are provided at the start of each data file. Bad or missing data (typically near the surface bins) are designated with 999.9.

3.1 Station 1 – Appendix A

Deployed at station 1 was a 600 kHz AWAC (Nortek). Data were collected in 1 m depth bins. The average depth of the meter through the deployment period was 18.2m. The first bin after blanking is 17.2m below the water surface. The AWAC data reach to the water surface. The last bin with a full set of usable data is 3.2m below the surface although data were collected intermittently at depths 1.2m and 2.2m during higher water periods. The following paragraphs describe the plots and tables presented in Appendix A.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Conversion of cm/s to feet/s: 30.48 cm/s = 1 ft/s.

Color contours of data quality parameters for vertical velocity and for each beam of the transducer heads of signal amplitude versus depth and time. Bottom graph is time history plot of average vertical velocity (cm/s) through the water column. Velocities are in cm/s. Amplitude is in counts.

Time history plots of water level (pressure sensor in m), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees True), and heading from the compass (degrees).

Time series vector plots of the measured currents at selected depths referenced to north. The length of the vector is equal to the speed of the current according to the speed scale (in cm/s). The direction of the

vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

Percent occurrence tables for each measured depth bin. Table shows the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

Current roses of percent occurrence of current speed versus direction for each depth shown in the time series vector plots. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

3.2 Station 2 – Appendix B

Deployed at station 2 was a 600 kHz ADCP (Teledyne RDI). Data were collected in 1 m depth bins. The average depth of the meter was 17.6m. The first bin after blanking is 15.5m below the water surface. The ADCP data reach to the water surface. The last bin with a full set of usable data is 2.5m below the surface although data were collected intermittently at shallower depths during higher water periods. The following paragraphs describe the plots and tables presented in Appendix B.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Conversion of cm/s to feet/s: 30.48 cm/s = 1 ft/s.

Color contours of current vertical velocity, error velocity, correlation, and intensity versus depth and time. Bottom panel is average vertical (water column average) velocity versus depth and time. Velocities are in cm/s. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Correlation and intensity are in counts.

Time history plots of water level (pressure sensor in m), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees True), and heading from the compass (degrees).

Time series vector plots of the measured currents at selected depths referenced to north. The length of the vector is equal to the speed of the current according to the speed scale (in cm/s). The direction of the vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

Percent occurrence tables for each measured depth bin. Table shows the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

Current roses of percent occurrence of current speed versus direction for each depth shown in the time series vector plots. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

3.3 Station 3 – Appendix C

Deployed at station 3 was a 1200 kHz ADCP (Teledyne RDI). Data were collected in 0.5 m depth bins. The average depth of the meter was 9.2m. The first bin after blanking is 8.1m below the water surface. The ADCP data reach to the water surface. The last bin with a full set of usable data is 1.6 m below the surface although data were collected intermittently at shallower depths during higher water periods. The following paragraphs describe the plots and tables presented in Appendix C.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Depth is measured as distance from the water surface.

Color contours of current vertical velocity, error velocity, correlation, and intensity versus depth and time. Bottom panel is average vertical (water column average) velocity versus depth and time. Velocities are in cm/s. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Correlation and intensity are in counts.

Time history plots of water level (pressure converted to depth in meters), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees), and heading from the compass (degrees True).

Time series vector plots of the measured currents at one meter depth intervals referenced to north. In these plots, the length of the vector is equal to the speed of the current according to the speed scale (in cm/s). The direction of the vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

For each measurement depth bin, a percent occurrence table showing the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

For each depth that a time series vector plot is provided, current roses are provided. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

3.4 Station 4 – Appendix D

Deployed at station 4 was a 1200 kHz ADCP (Teledyne RDI). Data were collected in 0.5 m depth bins. The average depth of the meter was 10.2m. The first bin after blanking is 9.1m below the water surface. The ADCP data reach to the water surface. The last bin with a full set of usable data is 1.6 m below the surface although data were collected intermittently at shallower depths during higher water periods. The following paragraphs describe the plots and tables presented in Appendix D.

Color contours of current speed versus depth and time, and current direction versus depth and time. Current speed is in cm/s. Current direction is in degrees True. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Depth is measured as distance from the water surface.

Color contours of current vertical velocity, error velocity, correlation, and intensity versus depth and time. Bottom panel is average vertical (water column average) velocity versus depth and time. Velocities are in cm/s. Conversion of cm/s to knots: 51.4 cm/s = 1 knot. Correlation and intensity are in counts.

Time history plots of water level (pressure converted to depth in meters), temperature (degrees Celsius), pitch and roll of the tilt sensor (degrees), and heading from the compass (degrees True).

Time series vector plots of the measured currents at one meter depth intervals referenced to north. In these plots, the length of the vector is equal to the speed of the current according to the speed scale (in cm/s). The direction of the vector equates to the current direction, with the current moving from the centerline toward the tip of the vector. North is towards the top of the paper, east to the right, south to the bottom, and west to the left.

For each measurement depth bin, a percent occurrence table showing the percent of the measurements within 4 cm/s speed bins, and 22.5-degree direction bins, is provided. Directions are degrees True.

For each depth that a time series vector plot is provided, current roses are provided. Speed ranges are color coded in 8 cm/s blocks (e.g., blue = 0-8 cm/s). Percent of occurrence is represented by the length of the color block. Full distance from the center of the rose to the circumference is 60%, midway is 30%. Directions are degrees True.

4.0 DATA DISCUSSION

4.1 Data Quality and Quantity

Current data from the four deployment sites exhibited data of high quality. This is illustrated clearly in the color contour plots of the data from the profiling meters (see sections 1 and 2 of each stations respective appendix).

The heading, pitch, and roll sensors indicate the moorings remained fairly steady throughout the deployment but all were deployed on a slight incline. The meters can compensate for these effects and data quality is not impacted. The meter for station 1 is mounted in a gimbal and shows some movement in the pitch and roll. Additional weights were added for deployment 4 and helped reduce rocking during tidal changes and ship wakes. The heading remained solid for meters at sites 1, 2, and 4. There was a small amount of heading change on the meter at site 3 near the middle and end of the deployment. These heading changes correspond with near surface elevations of error velocities and correlation indicating large vessel movement or docking nearby. There was no impact on the data quality.

Measurements from the water level gauge (tide station) installed in the EWW tracks well with the NOAA Seattle tide station (figure 2). There is some lag time between stations as expected due to geographic locations.

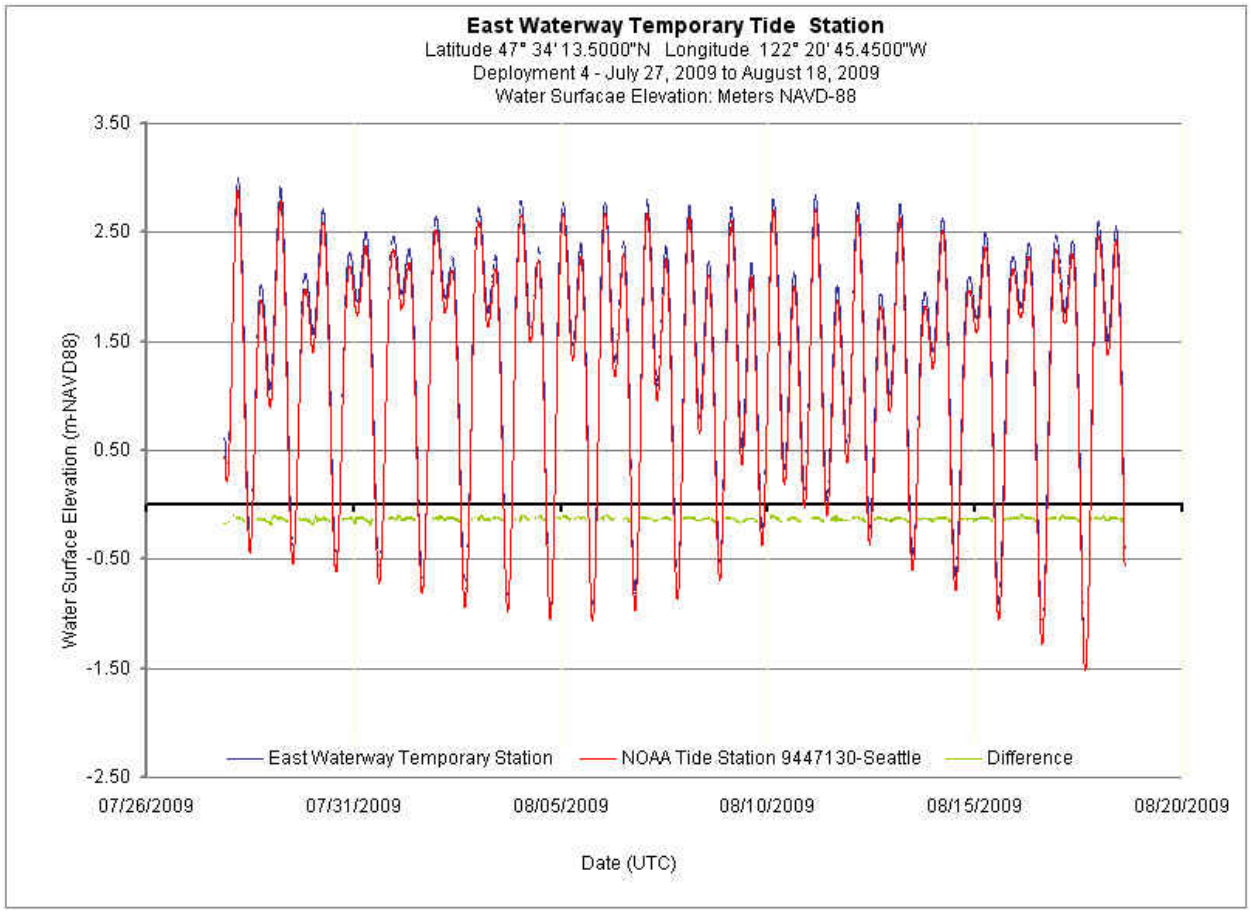

Figure 2. Comparison of tidal signal at temporary station in East Waterway and NOAA Seattle. Green line is difference between the measurements at both sites.

4.2 Data Results

Continuing the trend from the previous deployments, current flow is not uniform through the waterway. Also evident is both a tidal and river flow in the measurements. The temperature signatures at the four current meter sites show the water temperature generally stabilized at warm summer values above 11.75°C (53.15°F). At stations 1 and 2 the temperature averaged about 12.45°C and 12.37°C, respectively. At stations 3 and 4 the temperature at times exceeded 13°C although the average for station 3 was 12.35°C and for station 4 was 12.83°C. As with the past deployments the temperature record shows a tidal signal, generally becoming more pronounced moving up-river (intermittent at station 1 and seen in most of the record at station 4). In addition, another feature seen in the temperature record is several pulses of warmer water that last from 2 to 4 days. The first occurs 4-8 August and the second occurs 16-18 August. During these periods the water temperature increases about 0.5°C to 1°C and then drops back down. The signal is most evident in the record for station 4 and decreases in intensity moving toward the mouth of the waterway at station 1 indicating the possible influence of the river.

4.2.1 Currents at ADCP sites

At station 1 at the mouth of the EWW, the higher currents are evident in the upper 6m and decrease with depth until the very near bottom bin. Here currents near the seabed increase to speeds similarly seen at 6m depth. Current speeds generally remain below 12 cm/s; 73% to 92% for depths shallower than 7m, 96% to 99% for depths down to 17m, and 90% for the very near bottom depths. The maximum current speed recorded was 36.72 cm/s at 3.2m on 17 August. Average speeds ranged from 8.7 cm/s to 4.2 cm/s (Table 2). The percent occurrence products (tables and roses) illustrate the overall flow patterns. In the upper half of the water column (0 – 8m) water flow tends toward the north (out into Elliott Bay). Below this depth flow is toward the south. Maximum current speeds are all generally northward.

Table 2. Record statistics for currents at Station 1. All speeds are cm/s.

Depth	Data Pts	Avg East	Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
1.18	1280	2.39	2.64	8.7	27.3	82	0	0	3.6	42
2.18	2123	1.11	3.94	8.5	32.2	25	0	0	4.1	16
3.18	2630	-0.12	3.87	8.1	36.7	356	0.1	17	3.9	358
4.18	2968	-0.63	3.35	7.4	29.5	358	0.1	17	3.4	349
5.18	2982	-0.82	2.87	6.8	25.6	347	0	0	3.0	344
6.18	2991	-0.91	1.86	6.3	32.2	347	0	0	2.1	334
7.18	2990	-0.83	1.11	5.6	22.1	340	0	0	1.4	323
8.18	2992	-0.89	0.46	5.1	22.2	2	0	0	1.0	297
9.18	2992	-0.88	-0.03	4.7	19.5	5	0.1	17	0.9	268
10.18	2992	-0.88	-0.38	4.5	21.4	8	0	0	1.0	247
11.18	2989	-0.73	-0.68	4.2	19.5	317	0	0	1.0	227
12.18	2990	-0.70	-0.77	4.2	18.4	339	0	0	1.1	222
13.18	2988	-0.70	-0.93	4.3	21.2	352	0	0	1.2	217
14.18	2988	-0.65	-0.79	4.3	20.0	349	0	0	1.0	220
15.18	2990	-0.53	-0.56	4.4	21.5	357	0.1	17	0.8	223
16.18	2989	-0.44	-0.41	4.6	25.6	332	0	0	0.6	227
17.18	2985	0.73	-1.45	6.3	27.2	61	0	0	1.6	153

At station 2, currents are very low, decreased by half or more from the previous deployment. The majority of the the currents remain below 12 cm/s (94%-100% for all depths). The maximum current speed recorded was 21.1 cm/s at 2.5m depth. Average speeds ranged from 2.1 – 5.3 cm/s (Table 3), lower than the last deployment and continuing the trend of decreasing speeds with each successive deployment. There is a three-layer flow evident from the net currents. In the upper 4m the net flows are toward the north. At mid depth (5-10m) flow is toward the south. In the bottom depths flow is again northerly.

Table 3. Record statistics for currents at Station 2.

Depth	Data Pts	Avg East	Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
1.48	1544	-0.03	0.24	5.0	20.0	178	0.1	197	0.2	353
2.48	2226	-0.03	0.36	5.3	21.1	178	0.1	242	0.4	356
3.48	2672	-0.12	0.39	5.0	19.1	352	0.1	332	0.4	343
4.48	2983	-0.09	0.00	4.1	18.8	359	0	0	0.1	270
5.48	2991	-0.05	-0.43	3.4	20.2	7	0	0	0.4	186
6.48	2992	-0.06	-0.58	3.0	16.7	181	0	0	0.6	186
7.48	2997	0.00	-0.51	2.7	16.8	110	0	0	0.5	180
8.48	3001	0.04	-0.44	2.4	13.8	85	0	0	0.4	175
9.48	3002	0.00	-0.30	2.2	13.2	88	0	0	0.3	180
10.48	3002	-0.09	-0.21	2.1	13.0	95	0	0	0.2	203
11.48	3003	-0.14	-0.06	2.1	13.2	94	0	0	0.2	246
12.48	3003	-0.15	0.15	2.2	12.4	343	0	0	0.2	315
13.48	3003	-0.16	0.39	2.4	13.6	321	0	0	0.4	338
14.48	3003	-0.22	0.60	2.6	13.8	327	0	0	0.6	340
15.48	3003	-0.32	0.70	2.8	12.8	336	0	0	0.8	335

As with the previous deployments at station 3, the flow pattern continues to be NNE and SSW aligning with the bend in the waterway. The maximum current speed was 30.1 cm/s at 2.6m (Table 4), a 3 cm/s decrease from earlier measurements. Average currents were 2.3 – 9.1 cm/s consistent with previous results. This location again shows a definite two-layer flow. The upper half of the water column flows northward. The higher current speeds are also seen in this layer although 99% - 100% of the record is less than half a knot. In the lower part of the water column the flow is predominantly to the south. The current speed drops off significantly in the lower depths where over 90% of the record is below 8 cm/s.

Table 4. Record statistics for currents at Station 3.

Depth	Data Pts	Avg East	Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
0.59	1339	0.71	3.14	8.8	24.1	15	0.2	17	3.2	13
1.09	1796	0.26	2.30	9.1	24.0	38	0.1	287	2.3	7
1.59	2107	0.00	1.51	8.9	29.3	18	0.1	242	1.5	360
2.09	2357	-0.14	1.36	8.8	29.7	20	0.1	107	1.4	354
2.59	2617	-0.14	1.47	8.5	30.1	17	0	0	1.5	355
3.09	2885	-0.13	1.52	7.7	29.2	26	0.2	17	1.5	355
3.59	2987	-0.28	1.02	6.6	28.4	27	0	0	1.1	345
4.09	3011	-0.36	0.40	5.5	23.2	32	0	0	0.5	318
4.59	3015	-0.46	-0.24	4.4	19.9	9	0.1	107	0.5	242
5.09	3015	-0.63	-0.78	3.5	17.6	229	0.1	197	1.0	219
5.59	3015	-0.79	-1.13	3.0	16.7	225	0	0	1.4	215
6.09	3015	-0.86	-1.27	2.7	15.5	215	0	0	1.5	214
6.59	3014	-0.82	-1.26	2.6	15.4	233	0	0	1.5	213
7.09	3014	-0.68	-1.14	2.5	13.5	209	0	0	1.3	211
7.59	3014	-0.52	-0.98	2.4	14.3	216	0	0	1.1	208
8.09	3013	-0.37	-0.73	2.3	15.3	229	0	0	0.8	207

The junction site (station 4) continues to be the most energetic of all four measurement sites. The maximum speed was 49.0 cm/s at 6.6m (Table 5). This is the only site where currents reached above 1 knot although currents measured this deployment are about 10 cm/s less than the previous deployment. This continues the trend for all sites of slower currents this deployment compared to last deployment. The average speeds range from 9.9 – 14.4 cm/s. Flow is directed north and south and although the flow is very tidally driven, there is a net two-layer flow. In the upper half of the water column (above 3.5m) net flow is northward and maximum currents are to the north. Below the 4m depth range the net flow is southward and the maximum currents are directed south.

Table 5. Record statistics for currents at Station 4.

Depth	Data Pts	Avg East	Avg North	Avg Speed	Max Speed	Dir of Max	Min Speed	Dir of Min	Net Speed	Net Dir
0.09	1133	2.87	9.98	11.8	29.1	6	0.4	51	10.4	16
0.59	1610	2.72	8.47	11.8	29.5	27	0.1	17	8.9	18
1.09	1967	1.88	7.52	11.9	28.7	23	0.1	152	7.8	14
1.59	2237	1.32	6.09	11.8	28.8	14	0	0	6.2	12
2.09	2487	0.91	4.90	12.3	30.3	12	0.1	332	5.0	11
2.59	2758	0.57	3.94	12.9	35.1	186	0.2	17	4.0	8
3.09	2954	0.14	2.85	13.4	37.6	187	0.1	197	2.9	3
3.59	2993	-0.42	1.40	13.8	39.9	193	0.1	197	1.5	344
4.09	2993	-0.83	-0.05	14.2	41.5	186	0.1	17	0.8	266
4.59	2994	-1.33	-1.45	14.4	43.6	186	0.1	62	2.0	222
5.09	2994	-1.01	-2.63	14.2	46.0	191	0.1	197	2.8	201
5.59	2994	-0.87	-3.14	13.7	48.6	194	0.1	152	3.3	195
6.09	2994	-0.75	-3.29	13.1	48.3	194	0.1	332	3.4	193
6.59	2994	-0.63	-3.20	12.5	49.0	191	0	0	3.3	191
7.09	2994	-0.50	-2.86	12.0	47.9	189	0.1	287	2.9	190
7.59	2993	-0.29	-2.40	11.4	47.2	194	0.1	152	2.4	187
8.09	2993	-0.08	-1.87	10.9	46.6	191	0	0	1.9	182
8.59	2993	0.19	-1.36	10.4	45.4	190	0	0	1.4	172
9.09	2993	0.47	-0.87	9.9	44.6	189	0.1	242	1.0	152