Memorandum

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From: Coastal Monitoring Associates, LLC
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Date: 12/27/2007

Re: NW Natural Gasco Site Offshore Source Control Investigation – Seepage Results

Introduction

A seepage meter study was conducted on the Willamette River offshore from the NW Natural Gasco Site during the period extending from 10/04/07 – 10/07/07. Ultrasonic seepage meters were deployed at seven stations for periods of 2-3 days. The stations included three along the B transect line (GS-B2, GS-B5, GS-B7), two along the C transect line (GS-C5, GS-C7), one on the D transect line (GS-D5), and one in the pilot cap area (GS-PC1). The meters recorded seepage rates continuously over the deployment period, and the resulting data were used to develop time series plots of specific discharge in relation to river stage, as well as means specific discharge rates and statistical measures of variability of those rates.

Methods

Seepage rates were determined using ultrasonic seepage meters. These meters utilize an ultrasonic flow meter that relies on transit time difference between ultrasonic pulses traveling in the upstream and downstream directions. The flow meter is connected to an inverted funnel that seals into the mud line and serves to amplify the seepage rate as it moves through the flow meter. Prior to the field study, the seepage meters were calibrated over the expected flow range following using a high resolution peristaltic pump (Appendix A). A total of seven seepage meters were utilized. Six of these units were "remote" systems, meaning that the data logger and battery are housed on the same frame as the flow meter and seepage funnel, and the entire unit can be deployed remotely to the river bottom. The seventh unit was a "buoy" system, meaning that the data logger and the battery are housed in a buoy at the water surface, and connected to the flow meter and seepage funnel via a telemetry cable. The single buoy system supports two funnel/flow meter units. Remote systems were deployed to stations GS-B2, GS-B5, GS-B7, GS-C5, GS-C7, and GS-D5. The buoy system (with two funnel/flow meters) was installed at station GS-PC1. All installations and retrievals were made by divers operating from a

survey boat. Installation and retrieval times are shown in Table 1. For all stations except GS-PC1, data were recorded at a rate of 1 sample/minute and subsequently averaged to 15 minute intervals. At station GS-PC1, one of the meters recorded data at the 1 minute rate, and one meter recorded only at a 1 sample every 15 minute rate due to memory limitations.

Results & Discussion

Seepage data was successfully collected at 6 our of 7 target stations. For the seepage meter at station GS-B5, the data logger was not activated, so no results were obtained, and by the time the problem was found it was too late in the survey window to redeploy the meter. At station GS-PC1, the primary meter (1 sample per minute) became air-locked after about 4 hours so no useful data was recorded after that time. A flow meter can occasionally air-lock due to gas release from the sediment, in spite of the gas trap installed on each funnel. However, the secondary meter (1 sample per 15 minutes) successfully collected data throughout the deployment. Final data sets were trimmed on the front end to allow for equilibration of the flow meter. The end time for the data sets was determined either by when the unit was retrieved, or by when the battery ran out of power. Final data windows for each data set are summarized in Table 1.

Results for all stations are summarized in Table 2. Time series plots for specific discharge are shown in relation to river stage in Figure 1 – Figure 6. Mean seepage rates were low at all stations, ranging from a minimum of -0.05 cm/day at GS-B7 to a high of 1.47 cm/day at GS-D5. With the exception of GS-B7, the mean seepage rate at all stations was positive (discharge). In general, mean seepage rates were higher in the offshore stations along transects C and D compared to the inshore transect B. The mean seepage rate in the pilot cap at GS-PC1B was comparable to rates observed along the offshore transects (1.00 cm/day).

Temporal variations in seepage were minimal at GS-B2 and GS-B7 where the seepage was close to zero throughout the entire measurement period. All other stations showed some temporal variability, with the maximum variation at the pilot cap station GS-PC1B (Stdev = 3.04 cm/day). At GS-C5, temporal variations were observed, particularly during the last half of the measurement period, with a frequency of about 4 cycles per day and a range of about 2 cm/day. These fluctuations were not clearly correlated with tide/river stage. At GS-C7, seepage rates varied on a daily cycle with highest discharge generally corresponding with ebb tide, particularly the stronger ebb tides following higher high-water. Temporal variations at GS-D5 followed a similar pattern as GS-C7. At the pilot cap station GS-PC1, temporal periods of moderate discharge tended to correspond with lower high-water.

Overall, seepage rates were successfully quantified in the Willamette River offshore from the Gasco site. Seepage rates were generally low across the site, with near zero seepage along the B transect, weak discharge with tidal pulsing in the offshore C and D transects, and weak discharge with moderate pulsing during lower high-water in the pilot cap. Complete results are included in the electronic data deliverable including specific discharge, temperature, conductivity and river stage for each station.

Station	Seepage Meter	Deployment Period		Data Window		Position		Water Depth (ft)	Bottom Type
		Start	End	Start	End	Lat	Long		
GS-B2	US3	10/2/2007 15:00	10/5/2007 16:00	10/2/2007 21:00	10/5/2007 13:28	45.581110	122.760580	32	silty clay
GS-B5	US4	10/4/2007 16:50	10/6/2007 14:38	n/a	n/a	45.579953	122.757519	27	sandy silt
GS-B7	US1	10/2/2007 17:45	10/5/2007 14:30	10/2/2007 23:00	10/5/2007 14:15	45.579430	122.756070	32	silty clay
GS-C5	US2	10/4/2007 16:00	10/6/2007 14:16	10/4/2007 16:00	10/6/2007 14:15	45.580419	122.756923	46	silty sand
GS-C7	SM2	10/3/2007 16:11	10/6/2007 10:55	10/3/2007 17:00	10/5/2007 12:07	45.579775	122.755748	46	sandy silt
GS-D5	SM1	10/3/2007 12:38	10/6/2007 10:00	10/3/2007 19:00	10/6/2007 9:45	45.580100	122.754630	46	sandy silt
GS-PC1A	BS2-FT4	10/4/2007 16:00	10/6/2007 15:02	n/a	n/a	45.579966	122.758226	17	silt
GS-PC1B	BS2-FT7	10/4/2007 15:30	10/6/2007 15:06	10/4/2007 18:00	10/6/2007 14:45	45.579966	122.758226	17	silt

Table 1. Deployment times, data windows, positions, water depths and bottom type for each of the seepage meter stations.

Station	Specific Discharge (cm/d)			
	Mean	Min	Max	Stdev
GS-B2	0.05	-0.30	0.57	0.16
GS-B7	-0.05	-0.57	0.44	0.20
GS-C5	0.69	-0.65	2.57	0.82
GS-C7	1.38	-0.88	3.00	0.80
GS-D5	1.47	-0.38	4.59	0.99
GS-PC1B	1.00	-2.16	10.10	3.04

Table 2. Seepage results including mean, minimum, maximum and standard deviation of significant discharge.

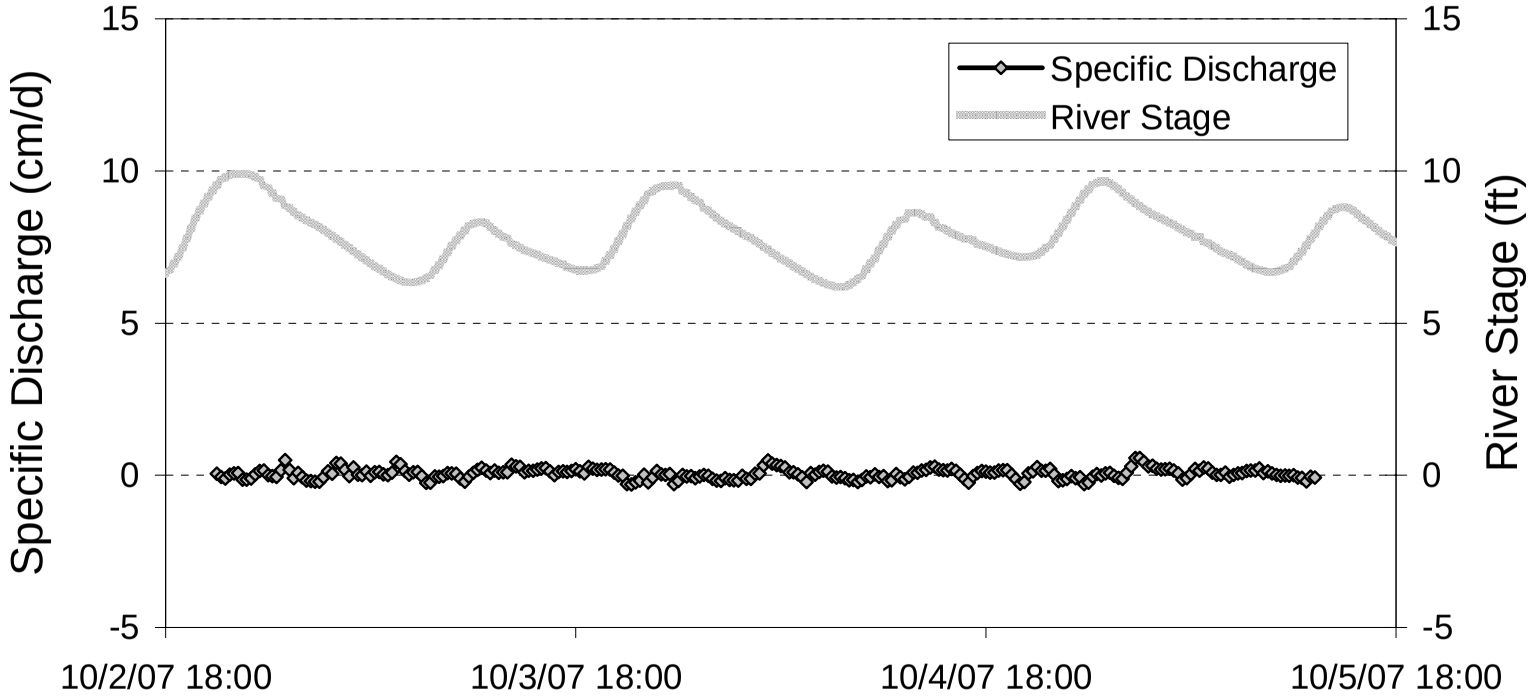


Figure 1. Time series of specific discharge and river stage (relative to city of Portland datum) at station GS-B2.

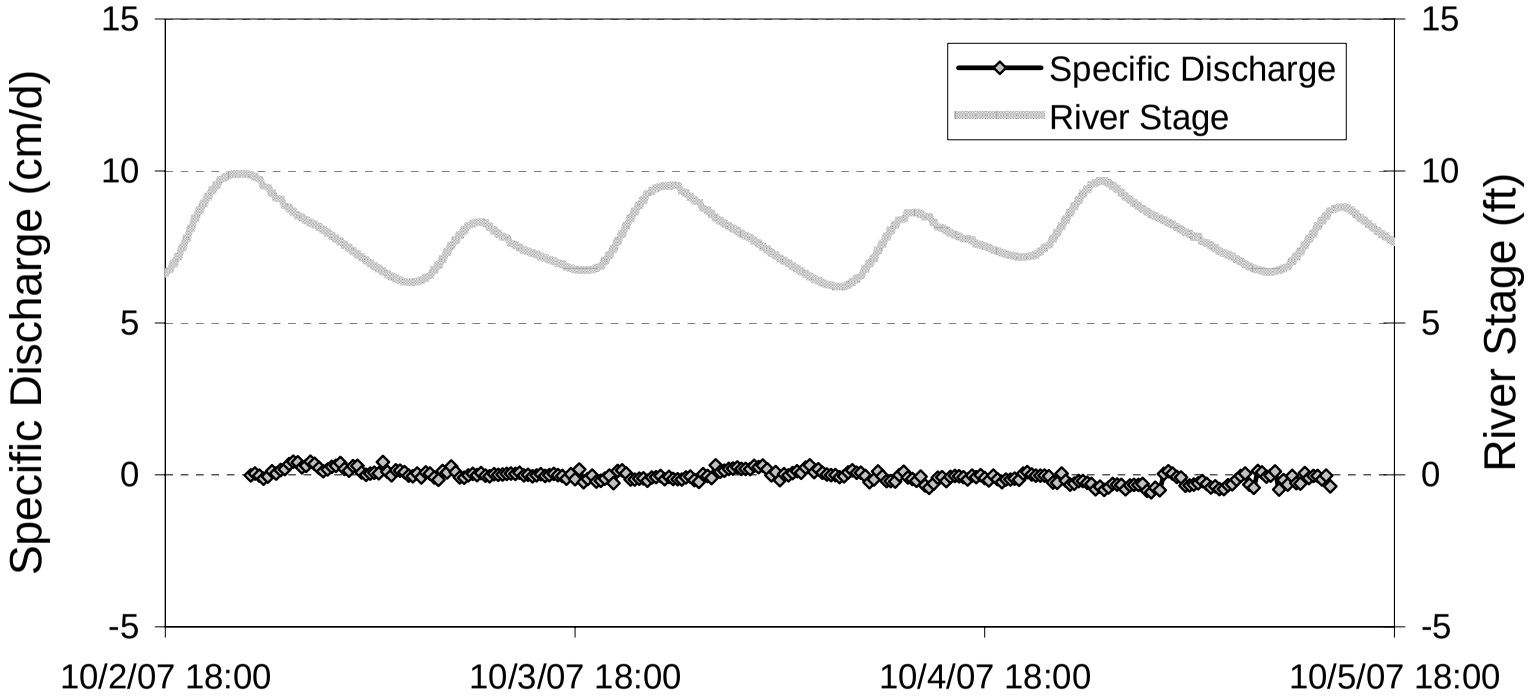


Figure 2. Time series of specific discharge and river stage (relative to city of Portland datum) at station GS-B7.

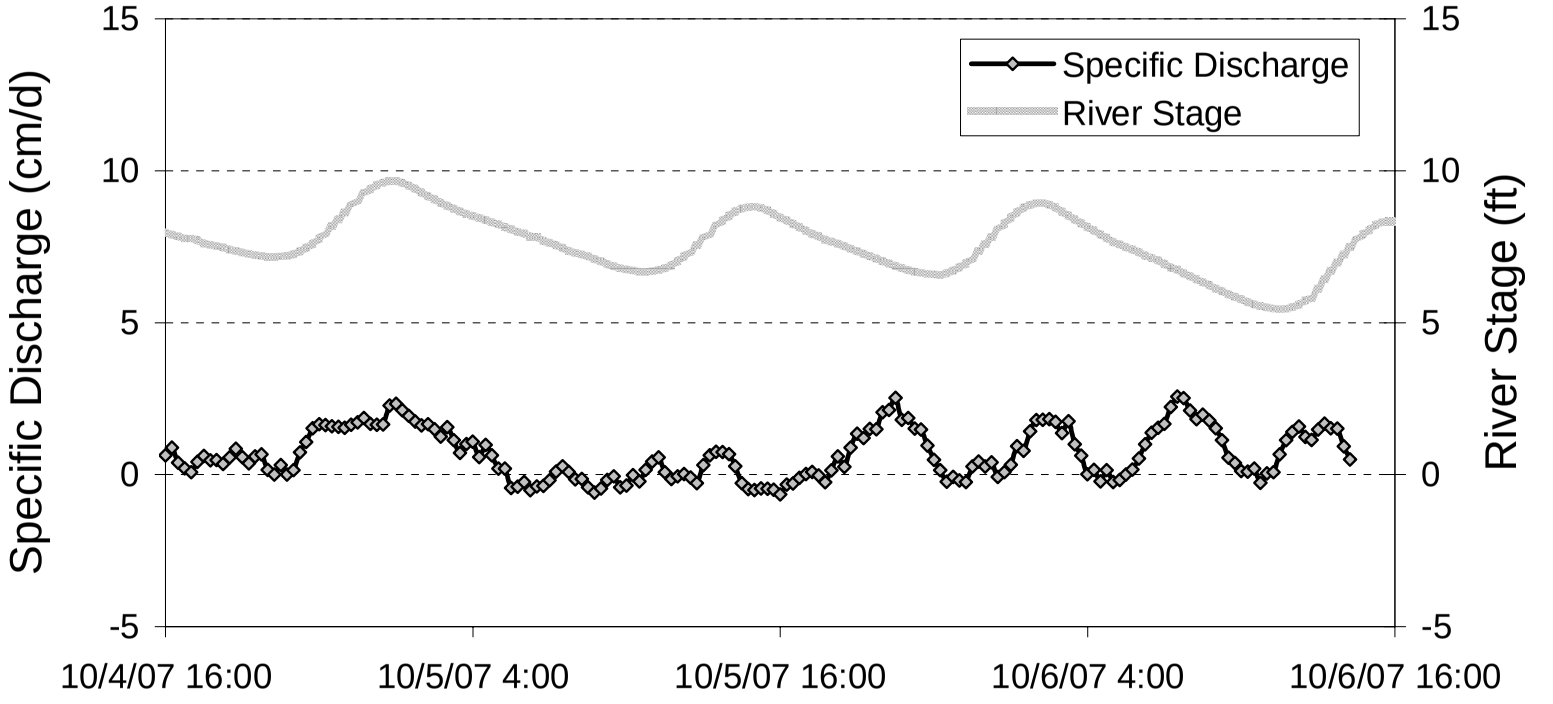


Figure 3. Time series of specific discharge and river stage (relative to city of Portland datum) at station GS-C5.

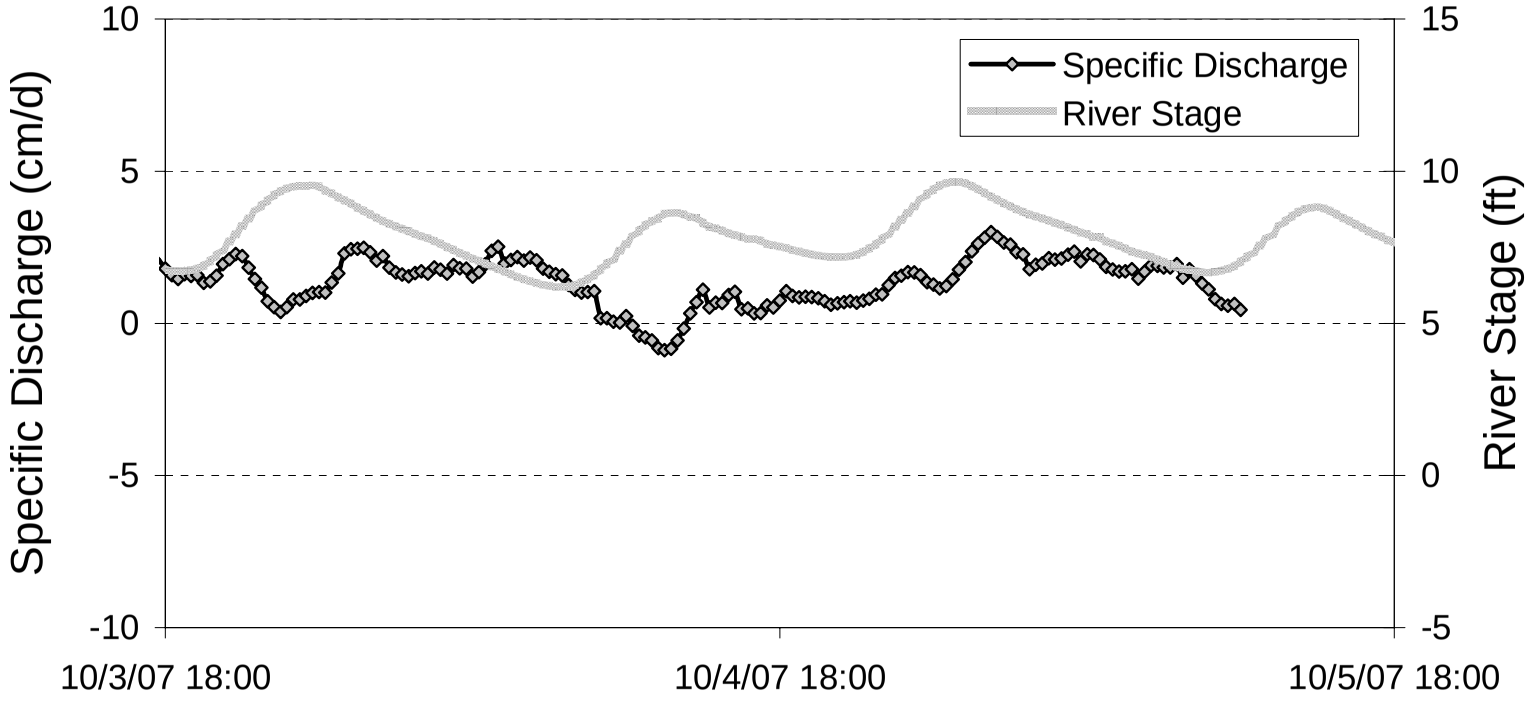


Figure 4. Time series of specific discharge and river stage (relative to city of Portland datum) at station GS-C7.

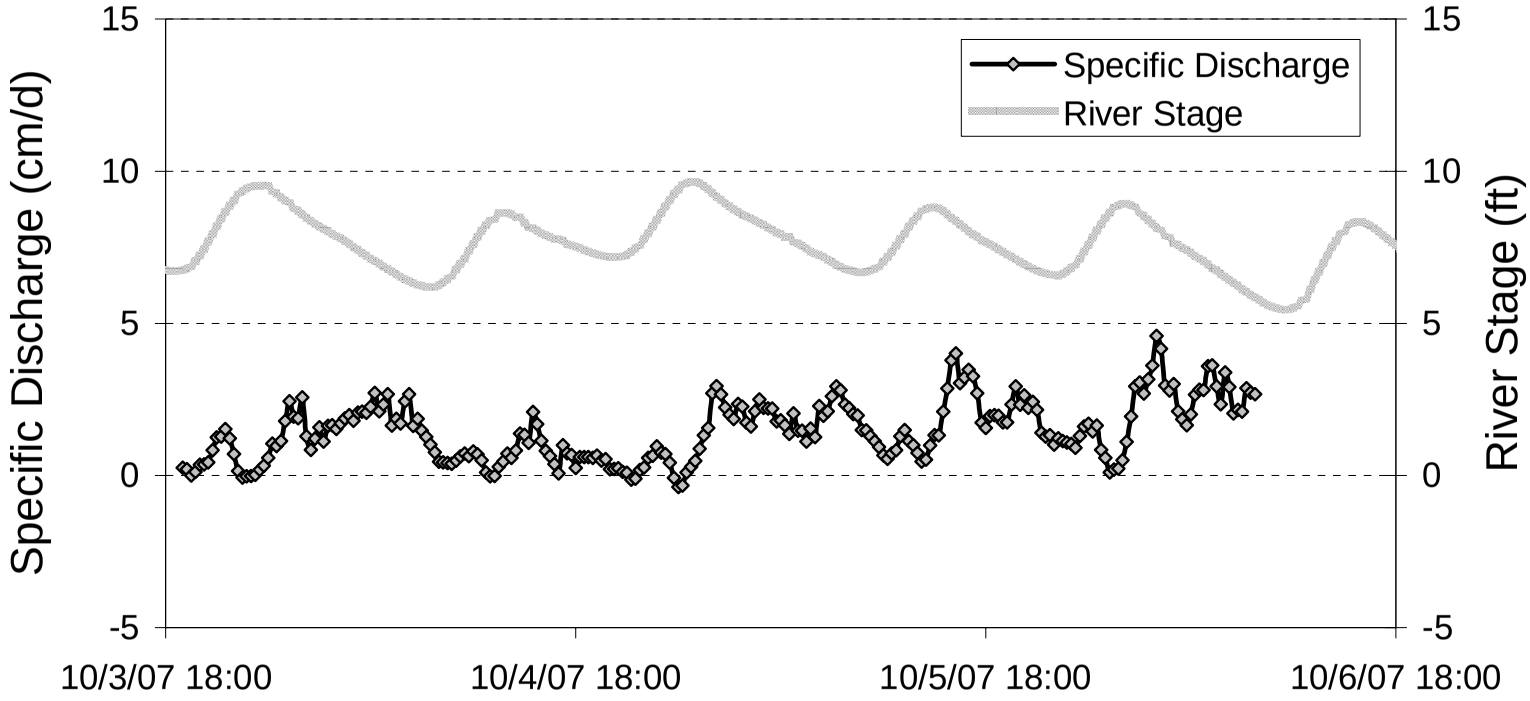


Figure 5. Time series of specific discharge and river stage (relative to city of Portland datum) at station GS-D5.

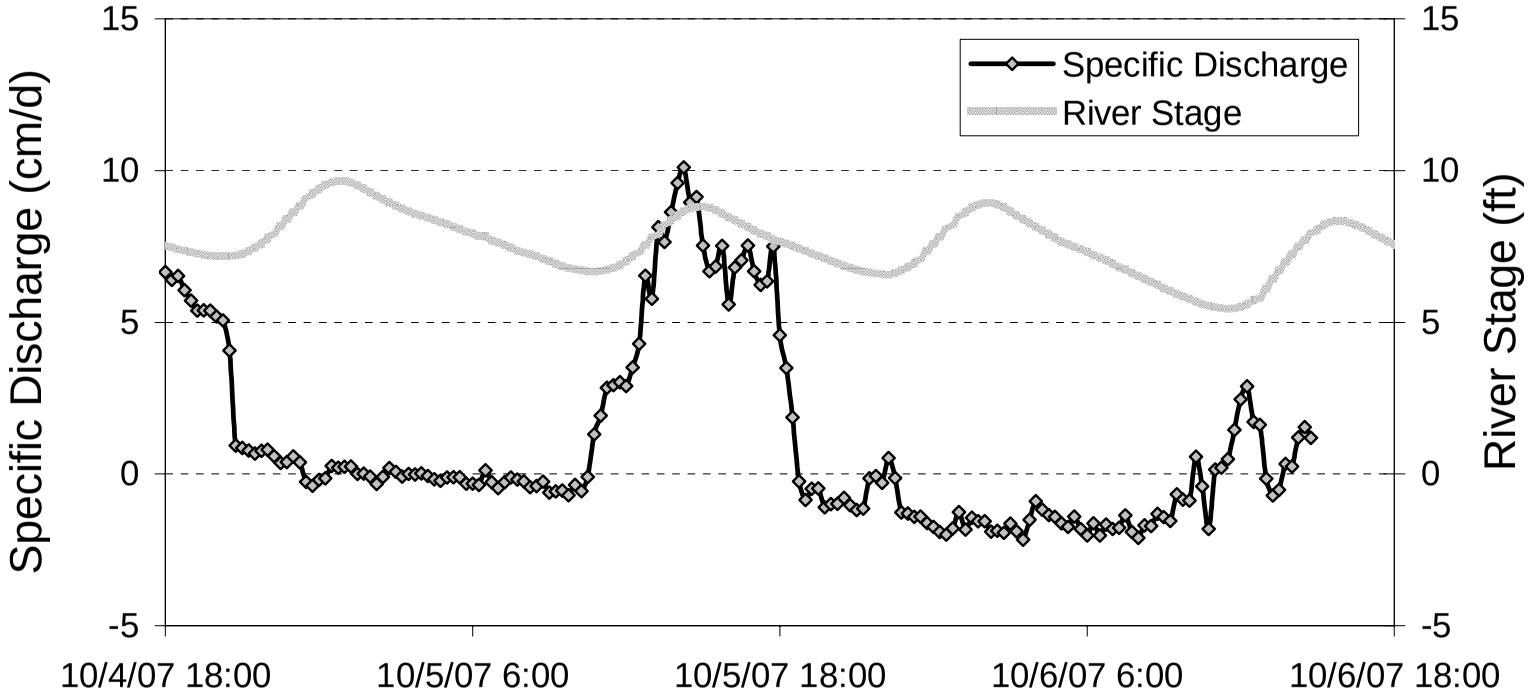
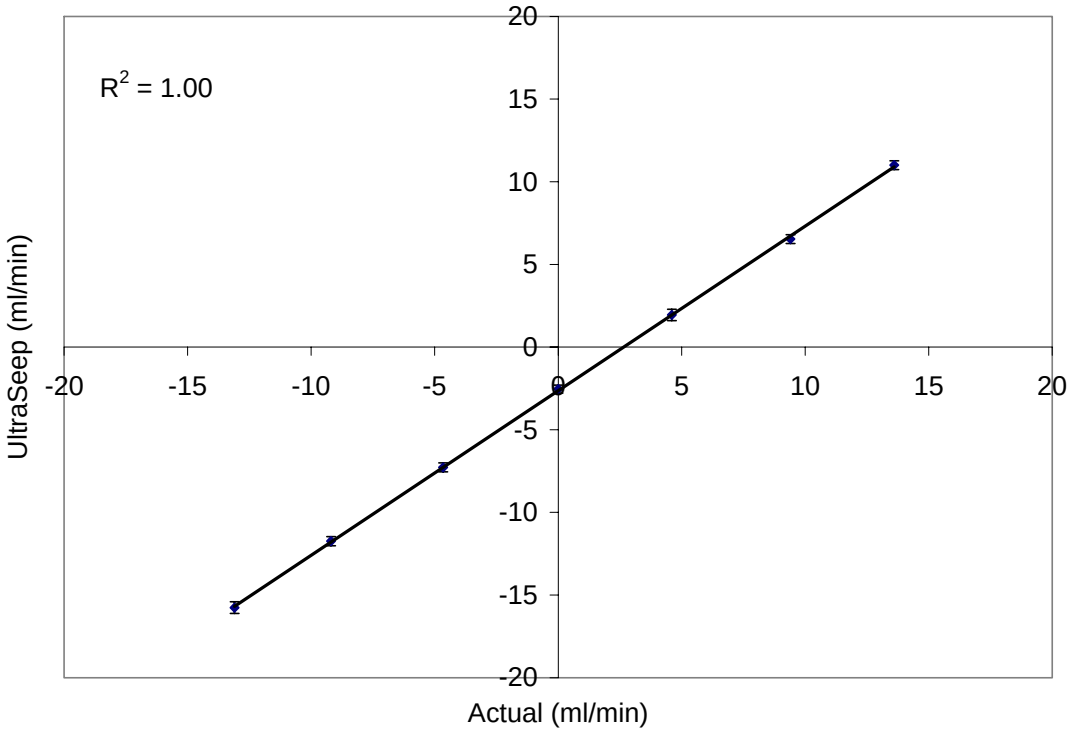


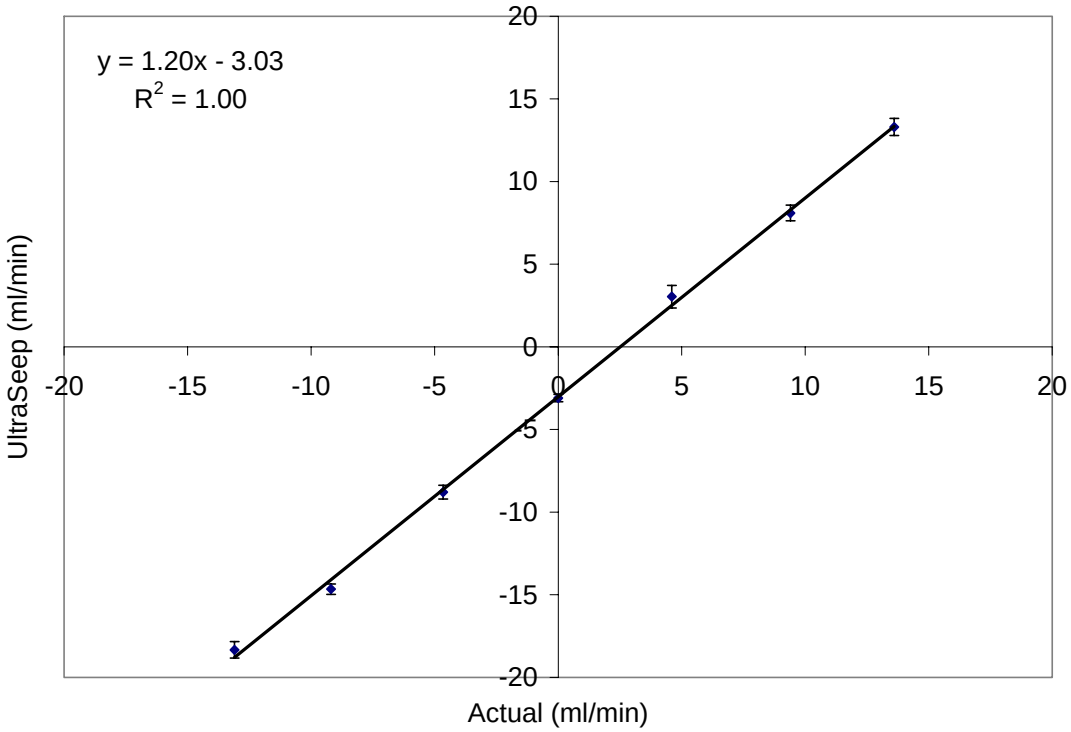
Figure 6. Time series of specific discharge and river stage (relative to city of Portland datum) at station GS-PC1B.

Appendix A

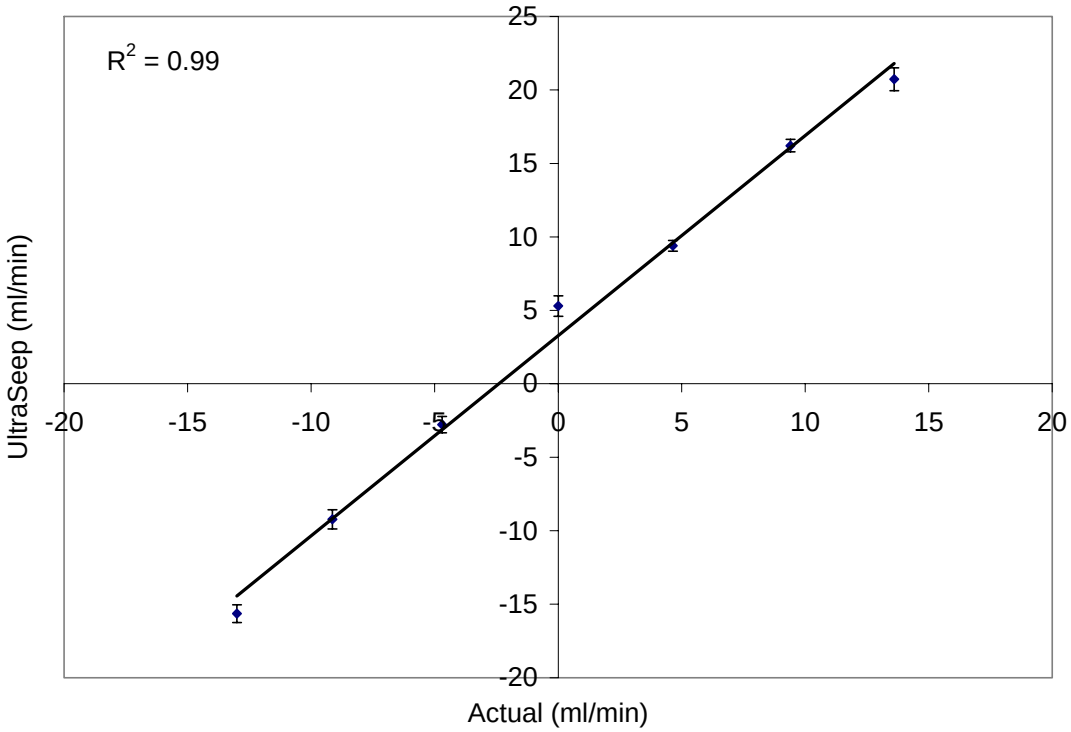
Seepage Meter Calibrations



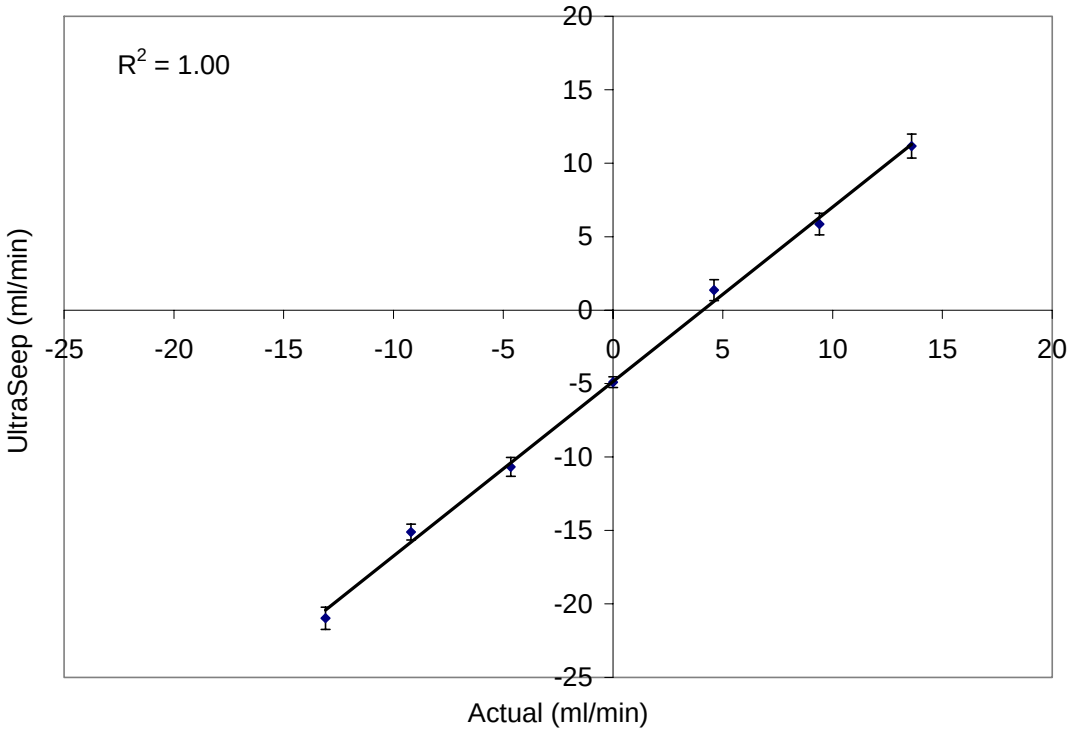
US3 Calibration



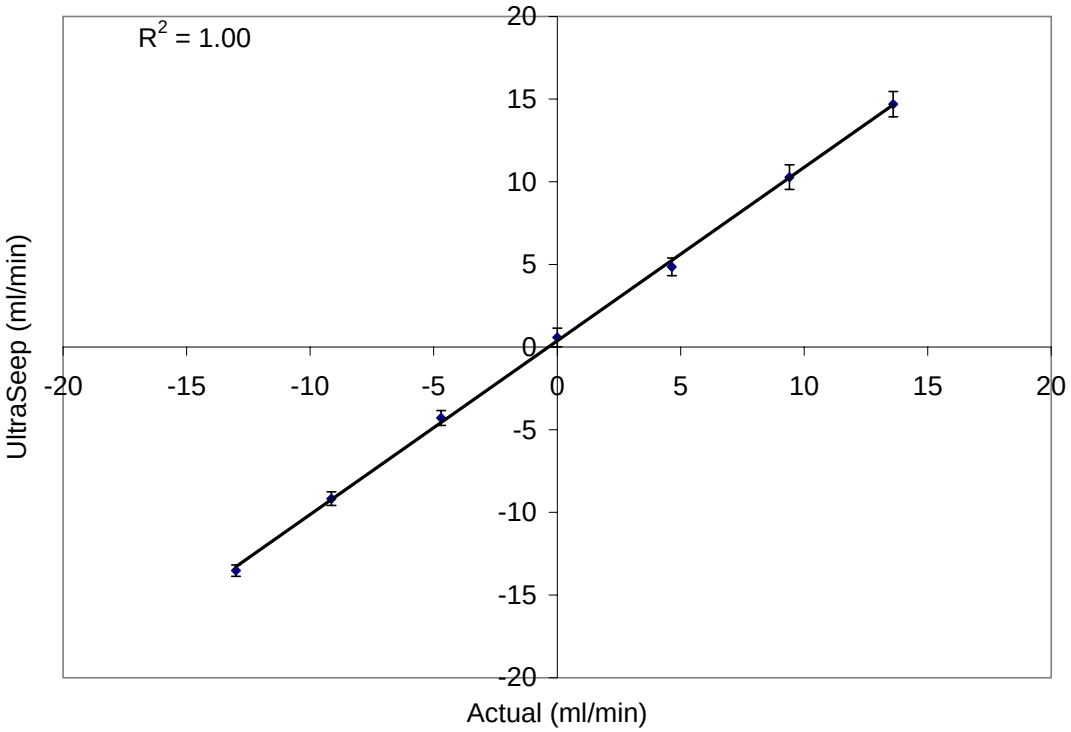
US1 Calibration



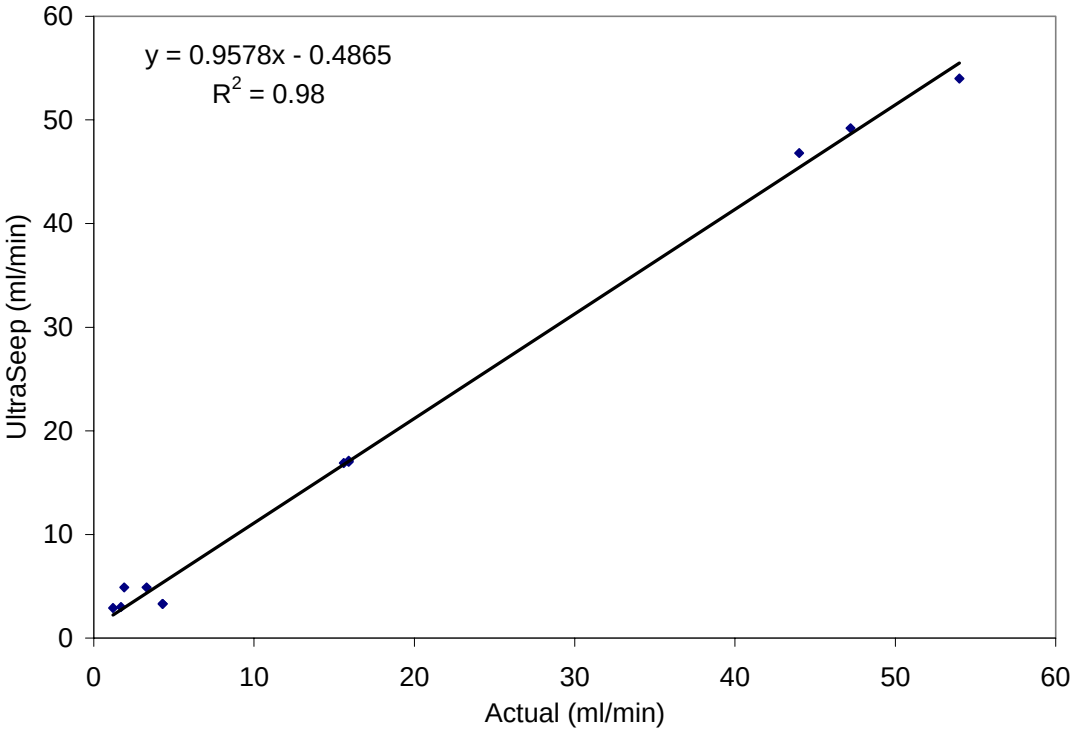
SM2 Calibration



US2 Calibration



SM1 Calibration



BS2-FT7 Calibration