High Resolution Salinity Profiling of the Stockton Deep Water Ship Channel during the Summer of 2012

Report 4.8.7

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List of Acronyms

CDEC	California Data Exchange Center
CFS	Cubic Feet per second
DWR	Department of Water Resources
DWT	Dead weight tonnage
DWSC	Deep Water Ship Channel
EERP	Ecological Engineering Research Program
mS	milliSiemens
MT	Metric tons
RRI	Rough and Ready Island
SJR	San Joaquin River
SpC	Specific conductance
TMDL	Total Maximum Daily Load

Introduction

The Port of Stockton is one of the nation's busiest harbors and has hundreds of shipping vessels arriving and departing each. Vessel capacity or dead weight tonnage (DWT) range in size from 7,000+ Metric Tons (MT) for general cargo and container vessels to 55,000+ MT for large bulk carriers (Port of Stockton, 2013). According to the International Maritime Organization, typical ballast water capacities for different types of ships range from 30% to 57% of the DWT (IMO GloBallast, 2013). Depending on vessel type, ballast is needed as cargo replacement, for vessel control, and in certain loading and unloading operations. In an effort to reduce the spread of unwanted 'stow-away' organisms, vessels traveling on international seas conduct a ballast water exchange in the open ocean before arriving at the destination port. The Port of Stockton conducts a ballast water inspection which requires all vessels to complete a ballast water inspection log to verify that ships are making open water exchanges.

The Ecological Engineering Research Program (EERP) at the University of the Pacific was hired as the lead scientific agency for the San Joaquin River Dissolved Oxygen Total Maximum Daily Load Project (SJR DO TMDL) (Project: E0883006, ERP-08D-SO3) in order to provide a scientific basis for management actions taken to meet TMDL requirements. As part of the adaptive management portion of this project, sonde surveys of the DWSC, between the Turning Basin and approximately 1 km downstream of Rough and Ready Island (RRI), were conducted as a preliminary investigation into the impacts of ballast water discharges from ocean going barges docking in the port of Stockton in 2012. The EERP had previously observed significantly higher values of specific conductance for samples taken near the bottom of the San Joaquin River (SJR) Deep Water Shipping Channel (DWSC) in or near the Turning Basin. As a result, specific conductance was one of the water quality parameters measured in these sonde surveys. The purpose of the analysis was to determine if there was a connection between salt plumes in the river and the release of ballast water by shipping vessels at the Port of Stockton. The results of the salinity analysis are presented in this report.

Methods

Study Area

Stockton's deepwater ship channel (DWSC), located on the San Joaquin River upstream in the San Francisco-Bay Delta, is a slow, tidally influenced body of water dredged to approximately 9-13 m deep and 150-350 m wide Figure 1 (Smith et al. 2004; Google Earth 2011). The SJR, upstream of the DWSC (south of Channel Point), is not dredged and is typically 2 - 3 m deep and 55 – 80 m wide (Smith et al. 2004; Google Earth 2011). Water velocities drop significantly at channel point where the shallow SJR enters the DWSC.

Data Collection

The Ecological Engineering Research Program (EERP) scientists conducted two initial surveys on June 7 and June 29, 2012 which were limited to vertical profiles at several locations in the DWSC. Subsequently, the EERP conducted four water quality surveys in the DWSC on July 5, August 2, August 16, and September 6, 2012 between 8am and 2:30pm. On September 6, 2012 the aerator at RRI was operating beginning at 9:15 am and continued throughout the rest of the day. YSI 6600 Sonde water quality sensors were deployed from a boat while slowly trolling along 3-5 km of the DWSC from the Turning Basin to approximately 1 km downstream of the RRI monitoring station at the northwest end of Rough and Ready Island (Figure 2). Latitude, longitude, and depth were recorded for spatial reference while temperature, specific conductance, pH, dissolved oxygen, turbidity, chlorophyll fluorescence (green algae), and phycocyanin (cyanobacteria) were recorded with a time-stamp every 4 seconds. During each of the surveys, the sampling crew stopped at some or all of the following locations: Rough and Ready Island, Light 45, Luis Park, Channel Point, Berth 12/13, Berth 10/11, and the Turning Basin (Figure 3) and the water quality sensors were slowly raised and lowered between the surface and bottom of these fixed locations, which will be referred to as “vertical profile data” in this report. “Survey data” will refer to all data taken during the four surveys, including vertical profile data and data taken between these profiles at various depths. The sonde instruments were calibrated before and after each study following EERP’s Quality Assurance Project Plan guidelines (Spier et al. 2011). The dates and locations of this study were originally chosen to conduct a preliminary investigation into the impacts of ballast water discharges from ocean going barges docking in the port of Stockton in 2012.

Continuous monitoring flow data collected at Garwood Bridge Monitoring Station (Figure 1) was obtained through the California Data Exchange Center (CDEC) webpage and used to characterize the flow into the DWSC.

Survey data collected by DWR in the DWSC was provided by Christine Joab with the Central Valley Regional Water Quality Control Board for comparison to data collected by EERP. DWR’s specific conductance samples were collected using a YSI 6600 multiparameter data sonde at both the near surface and near bottom locations.

Data Analysis

Data was reviewed to remove erroneous sensor readings such as the sensor hitting the channel bottom and stirring up sediment. All data with turbidity values greater than 30 NTU, which is not normally observed in the DWSC, were assumed to have hit the bottom of the channel and were removed. Reviewed data was visualized in Grapher (Golden Software, Inc.) as contour plots using an inverse distance algorithm. Contour plots included the entire up to downstream transect on a given survey date. Each vertical profile was plotted on XY scatter plots in Grapher. The data was geospatially analyzed using ArcGIS 10.0 (Esri, Redlands, CA).

Results and Discussion

Initial Vertical Profile Survey

Average net flow into the DWSC from the SJR was nearly zero during most of the study period from early July through the middle of September 2012 (Figure 4). The first survey on June 7, 2012 showed an area of higher conductivity water in the bottom half (20 to 40ft) of the water column within the Turning Basin (Figure 5). The second survey on June 29, 2012 showed only a slight increase in salinity in the bottom half of the water column within the Turning Basin (Figure 6).

Spatial and Temporal Variation in Salinity in the DWSC

After reviewing data from the first two surveys, the study area was expanded to include points from the Turning Basin, the mouth of the SJR (at Channel Point), and all the way down stream past the Rough and Ready Island monitoring station (Figure 3). Contour plots of the four surveys are presented in Figures 7-10. The results of the vertical profiles are given in Figures 11-14.

On the July 5, 2012 survey, a salt plume of 3.4 mS/cm was concentrated at a depth of about 40 ft and a distance of approximately 2.9 km, corresponding to the lateral position at dock Berths 12 and 13 (Figure 7). Berths 12 and 13 are located where the SJR enters the DWSC (Figure 1). The data collected from the SJR upstream of the DWSC at Rough and Ready Island did not show signs of increased salinity and the specific conductance of the SJR was consistent with background values of about 0.7 mS/cm in the DWSC (Figure 11). Multiple sampling passes were made around the salt plume and it was found that the concentration of salt diminished in every direction leading away from Berths 12 and 13, indicating that the saltier water did not originate upstream.

The study conducted on August 2, 2012 indicated steady specific conductance values for the entire study area in both the lateral extent and vertical profiles (Figures 8 and 12). Specific conductance readings averaged 0.703 mS/cm with a standard deviation of 0.026. The August 16, 2012 study revealed a region of higher conductivity near the bottom of the channel, located near the Turning Basin (Figure 9 and 13). This higher salinity plume occurred east of the salinity plume observed in the July 5, 2012 study. A vertical profile was taken near the Rough and Ready Island monitoring station that showed the salinity did not increase with depth and the plume had not migrated downstream (Figure 13). The high conductivity measurements observed by the EERP in the DWSC were corroborated with findings from a concurrent water quality survey conducted by the Department of Water Resources (Christine Joab, personal correspondence).

The last survey was conducted on September 6, 2012, while there were multiple vessels in port both loading and unloading cargo. The vertical profiles did not show significant changes in salinity with increasing depth (Figure 14). The contour plot of the DWSC showed the conductivity was uniform (0.690 mS +/- 0.014) throughout the entire study area (Figure 10).

Influence of ballast water

The capacity of ballast water in large shipping vessels is enough to account for the higher conductivity plumes measured in the DWSC. It was hypothesized that empty ships arriving at port would be carrying ballast water that is discharged upon loading of the ships with cargo. A typical dry bulk vessel has a DWT of 38,000 MT. 30% or more of this weight may be carried as ballast and potentially discharged upon loading of the ship. Seawater contains approximately 35 kg of salt per cubic meter and 12,000 cubic meters or more could be discharged from such a ship.

If this amount of salt water were diluted into the DWSC to a concentration equal to the highest value measured during the study (3.4 mS/cm), this theoretical plume would cover nearly the entire width of the DWSC (150 m) over 500 m in length, and up to 3 m deep. Such a plume (over 225,000 cubic meters) would cover a significantly larger area than what was measured during any of the DWSC surveys.

The final survey was conducted on September 6, 2012 while a vessel was in port at Berths 12 and 13. According to the online port of Stockton ship log, the ship was loading coal, had arrived on August 30, 2012 and was scheduled to depart September 7, 2012. The dry bulk vessel called the Moku Pahu that had a DWT of 37,654. Assuming the average ballast value of 30% DWT discharged, a potential water volume of 11,296 cubic meters could be released from this vessel. During the study, the ship was seen listing towards the stern while coal was being loaded and water was observed pouring out of multiple ports on the sides of the ship (Figure 17). Despite high shipping traffic that day and the observed discharge, there were no significant differences in specific conductance detected.

Table 1 summarizes for each survey date if a vessel was in port and if salt water plumes were observed in the DWSC. Overall, there was no apparent correlation between the presence of ships in port and high salinity measurements.

Conclusions

The lateral surveys and vertical profiles conducted by EERP between June and September 2012 showed intermittent high salinity plumes localized to within a few meters of the channel bottom, in and around the loading docks and in the Turning Basin. No apparent relationship was found to relate high salinity in the DWSC with the presence of vessels in port.

Acknowledgements

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References

Google Earth (2011). "Deep Water Ship Channel" (37.959, -121.331). 9/15/2011, accessed on 10/18/13.

IMO GloBallast (2013). "GloBallast Management Programme: The Problem", accessed on 11/8/13. < http://globallast.imo.org/ >

Port of Stockton (2013). “Port of Stockton Daily Vessel Log” accessed on 11/8/13. <http://www.portofstockton.com/project/view-log>

Smith, R. E. and A. Foxgrover (2004). The file delta_v2.asc is an integer grid of water depth. Produced using the ArcInfo TOPOGRID routine. The grid was then exported to a flat file format using ASCIIGRID. The grid was developed from a database of point soundings assembled by the California Department of Water Resources (http://modeling.water.ca.gov/ delta/models/dsm2/tools/csdp/index.html). Additional information on the procedures used to develop the grid are available online at (http://sfbay.wr.usgs.gov/access/Bathy/Delta/index.html). U.S.Geological Survey. Menlo Park and Santa Cruz, CA.

Table 1. Summary of Salt Water Plumes Observed, Vessel at Bulk Goods Loading Dock, and SJR Flow.

Sampling Trip Date	Higher Conductivity Observed Near Channel Bottom	Ship in port at Berth 12/13 (loading)	5-Day Running Mean Daily Flow (CFS)
6/7/2012	Yes	Not known	395
6/29/2012	Yes (slight)	Yes	301
7/5/2012	Yes	Yes	141
8/2/2012	No	No	-119
8/16/2012	Yes	No	-129
9/6/2012	No	Yes	24

Figure 1. Deep Water Ship Channel (DWSC) study area. Geometry of the DWSC and un-dredged San Joaquin River south of Channel Point.

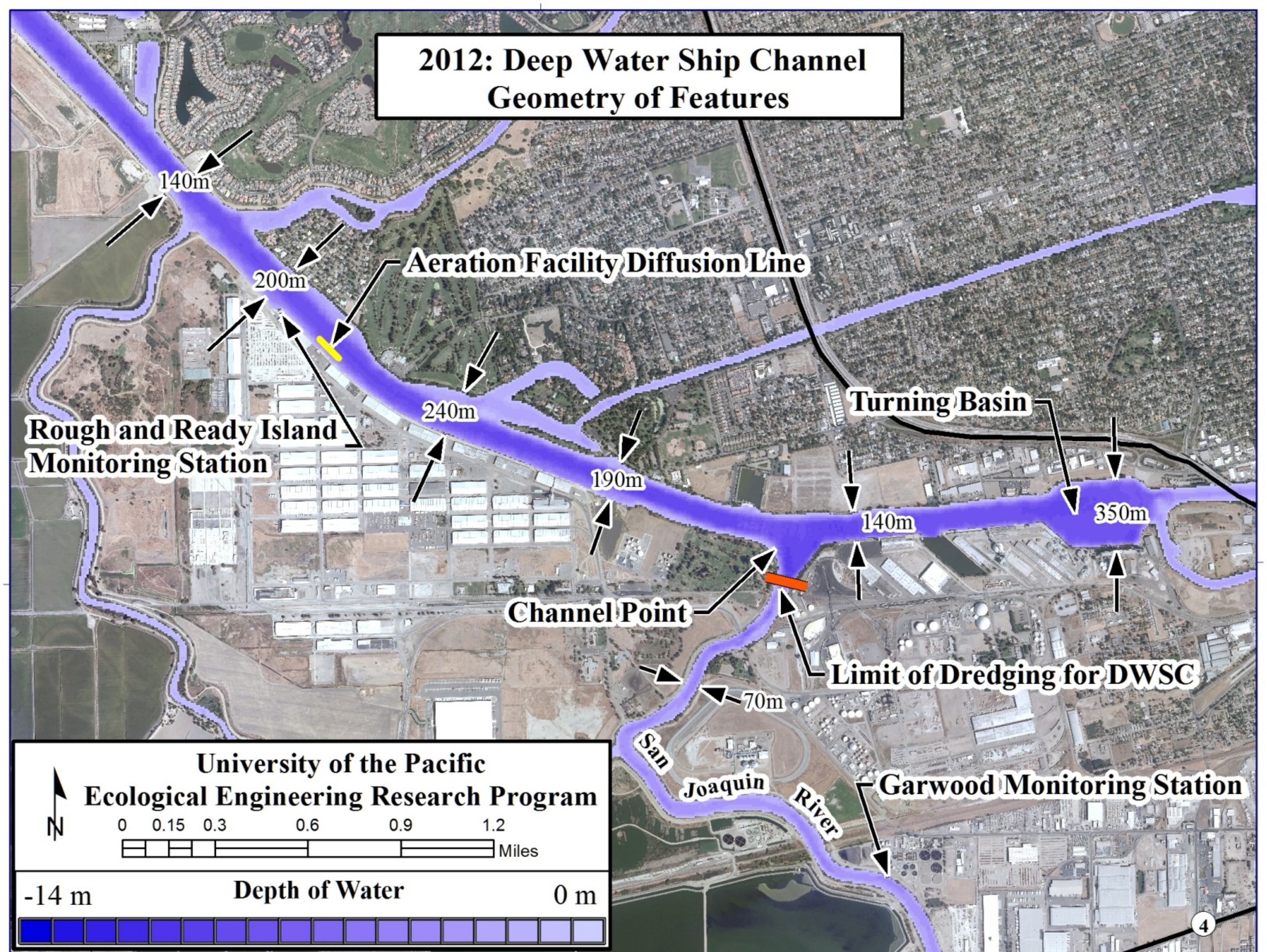

Figure 2. Deep Water Ship Channel (DWSC) study area. Lateral profile extent within the DWSC.

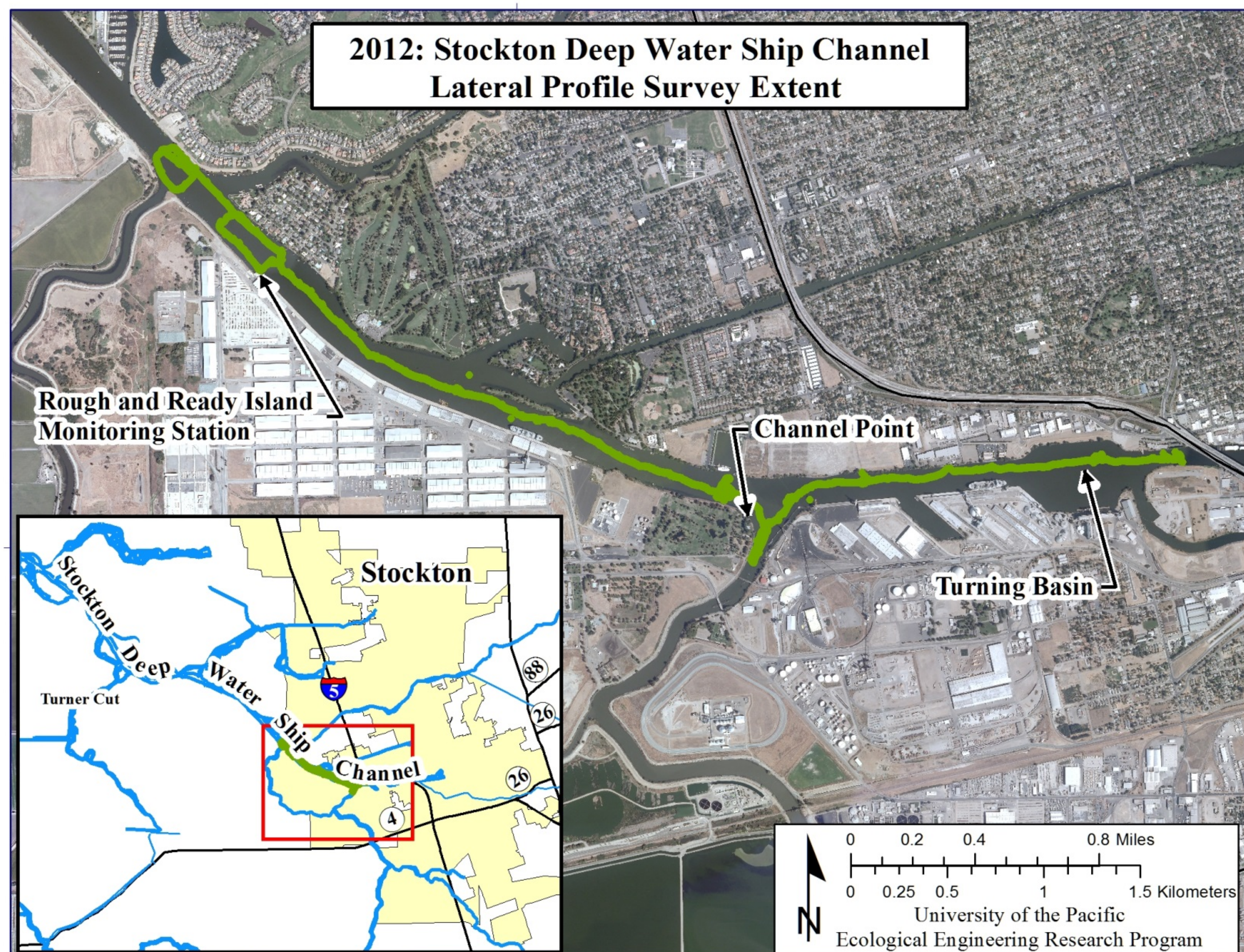

Figure 3. Deep Water Ship Channel (DWSC) study area. Locations of vertical profiles.

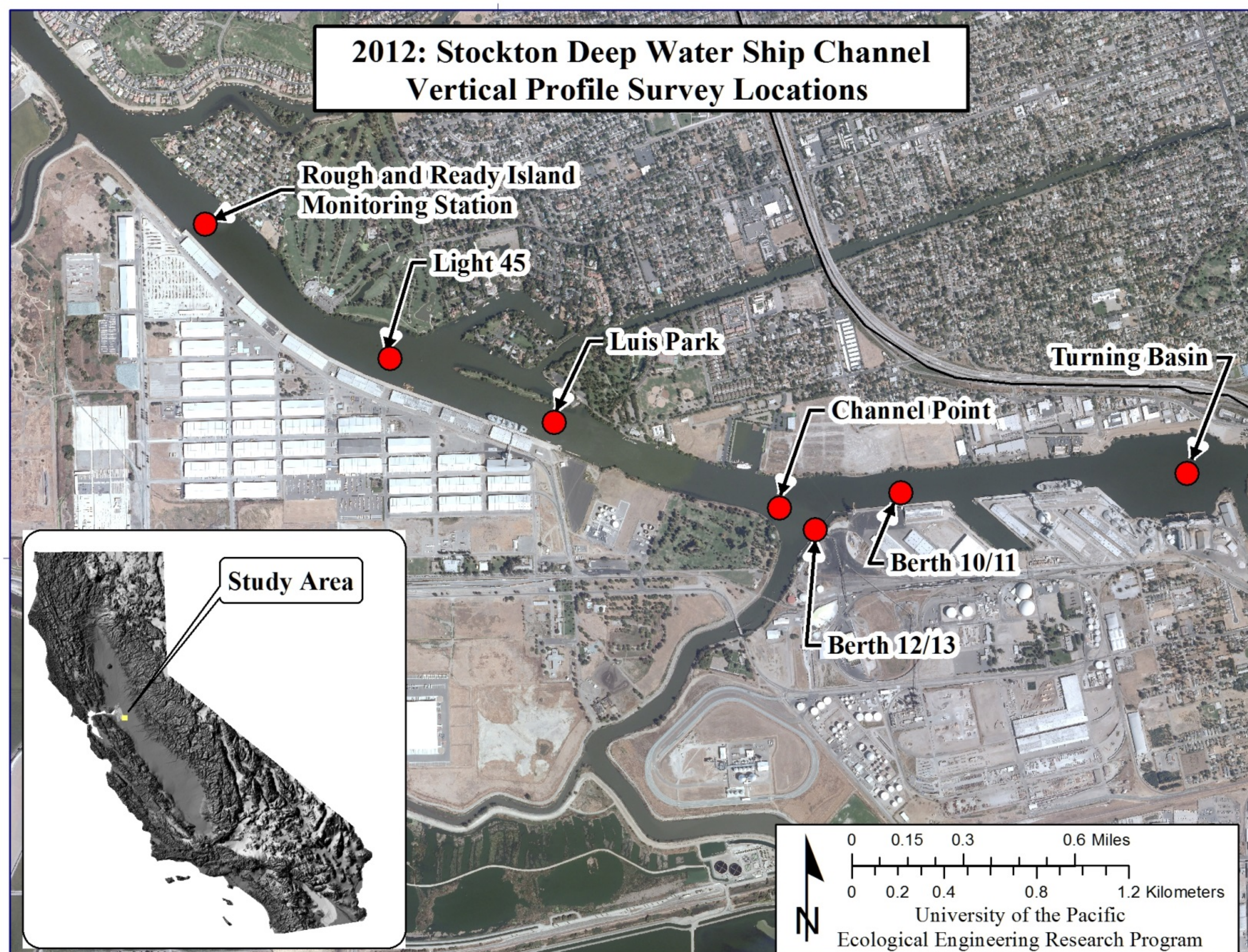

Figure 4. Flow data at the Garwood Bridge monitoring station from online CDEC database for May to September 2012.

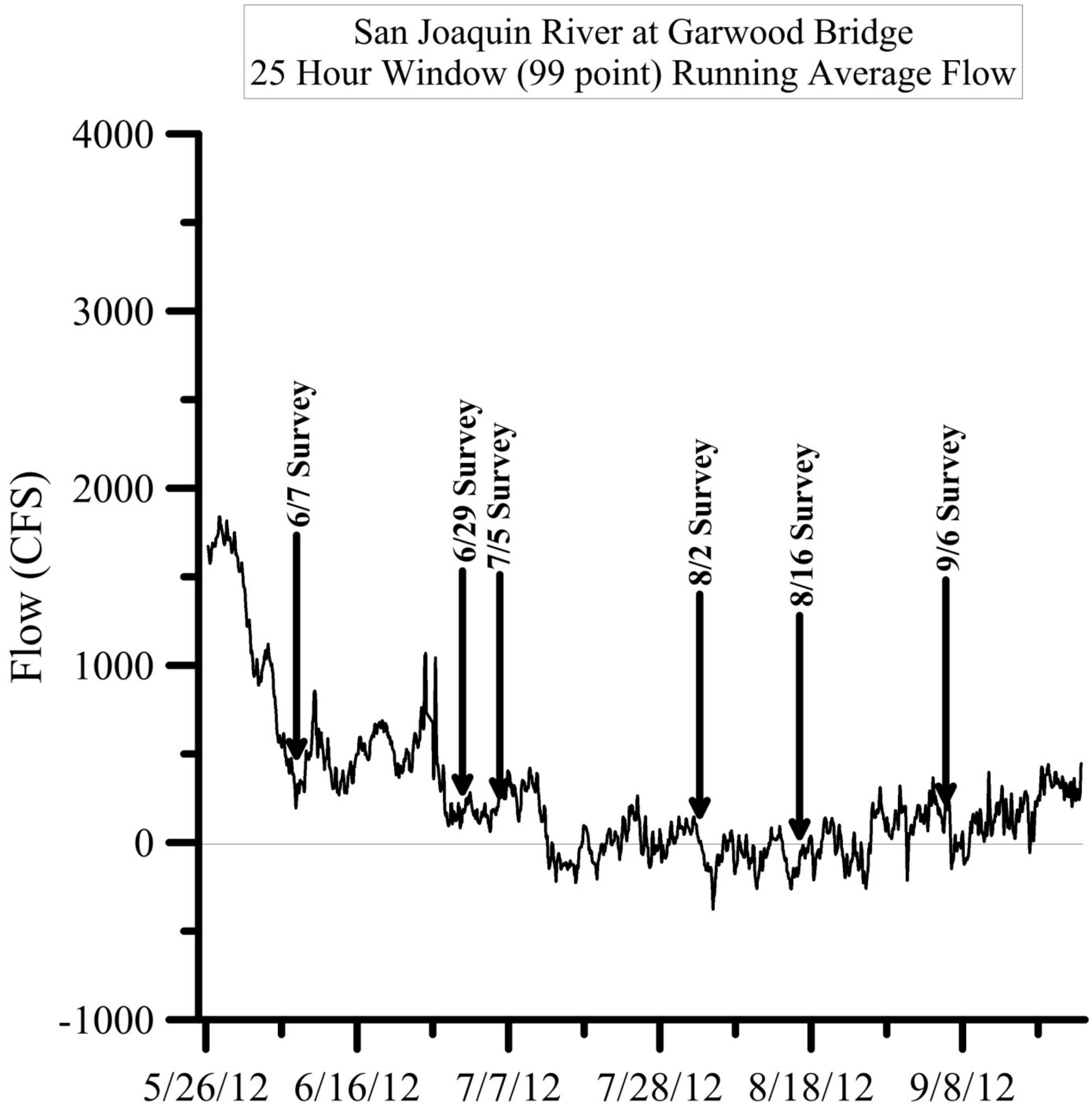

Figure 5. Specific conductance (SpC) profiles measured on June 7th 2:36pm – 2:48pm, 2012 by the Ecological Engineering Research Program (EERP). Department of Water Resources (DWR) (SpC) measurements 1 m below the surface and 1 m above the river bottom measured on June 4th 12:35pm, 2012 for comparison.

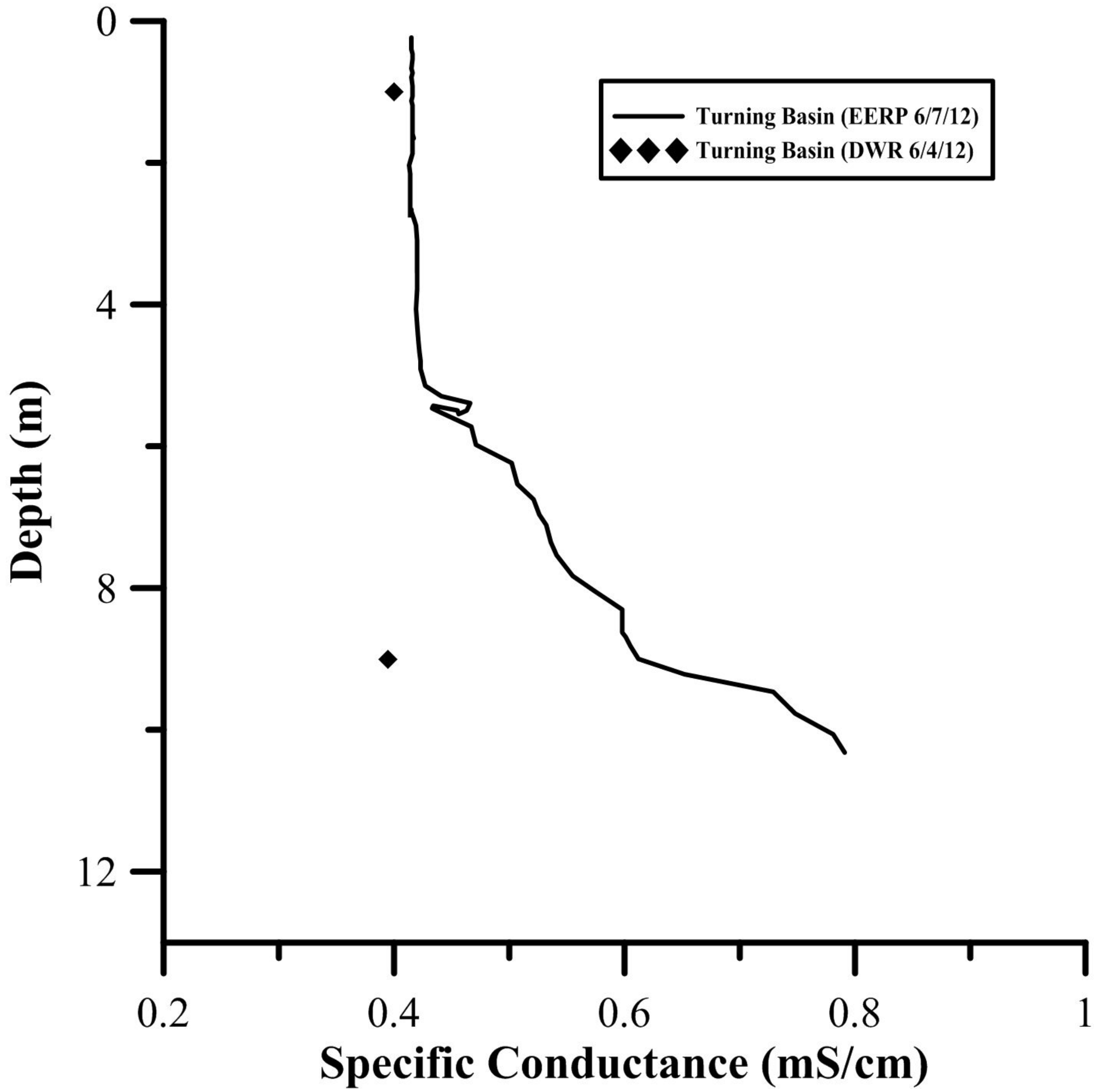

Figure 6. Specific conductance (SpC) profiles measured on June 29th 8:00am – 9:23am, 2012 by the Ecological Engineering Research Program (EERP). Department of Water Resources (DWR) (SpC) measurements 1 m below the surface and 1 m above the river bottom measured on July 2nd 11:40am - 11:55am, 2012 for comparison.

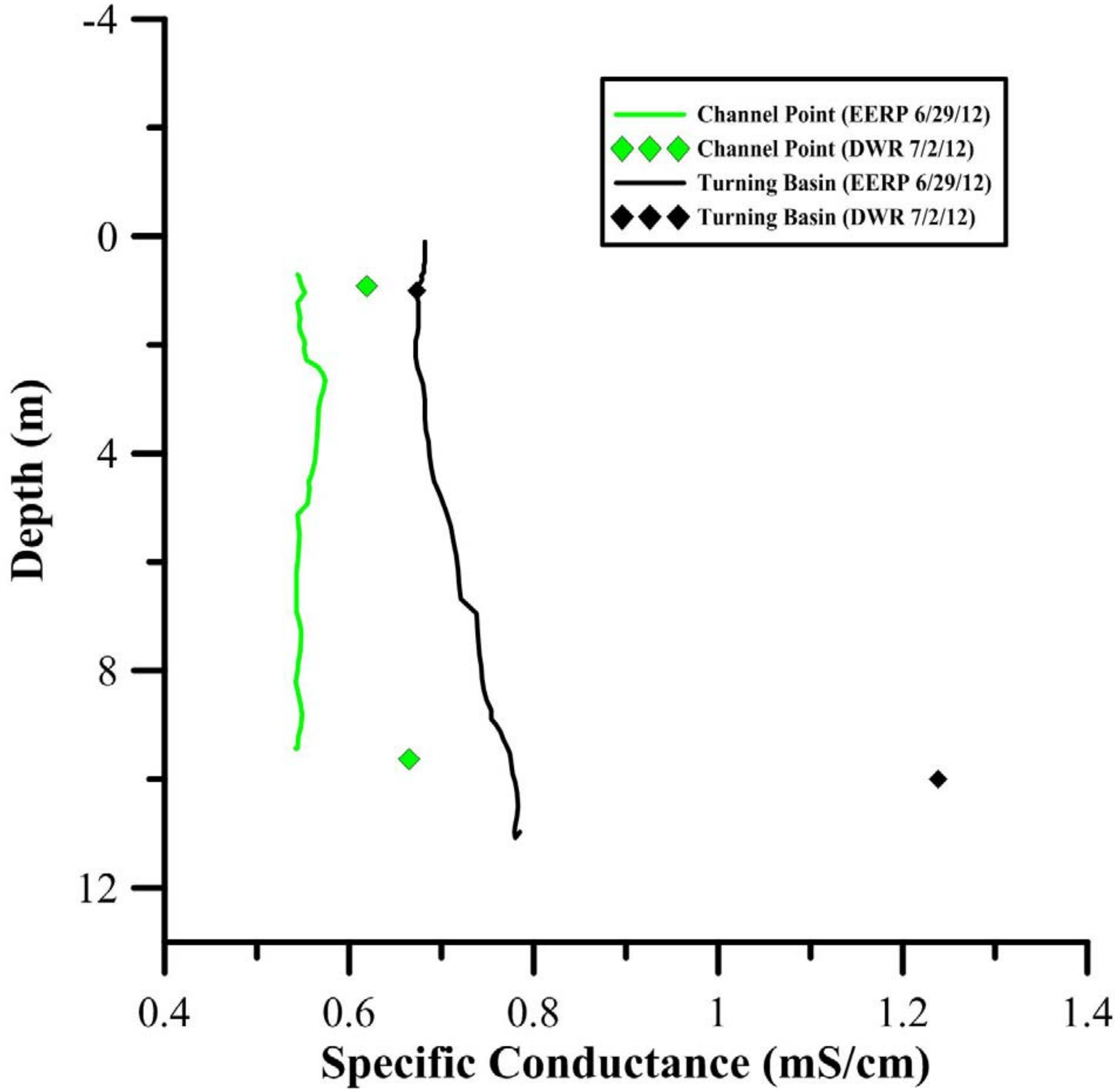

Figure 7. Contour plot of specific conductance as a function of depth and distance upstream from the Rough and Ready Island Monitoring Station on July 5, 2012.

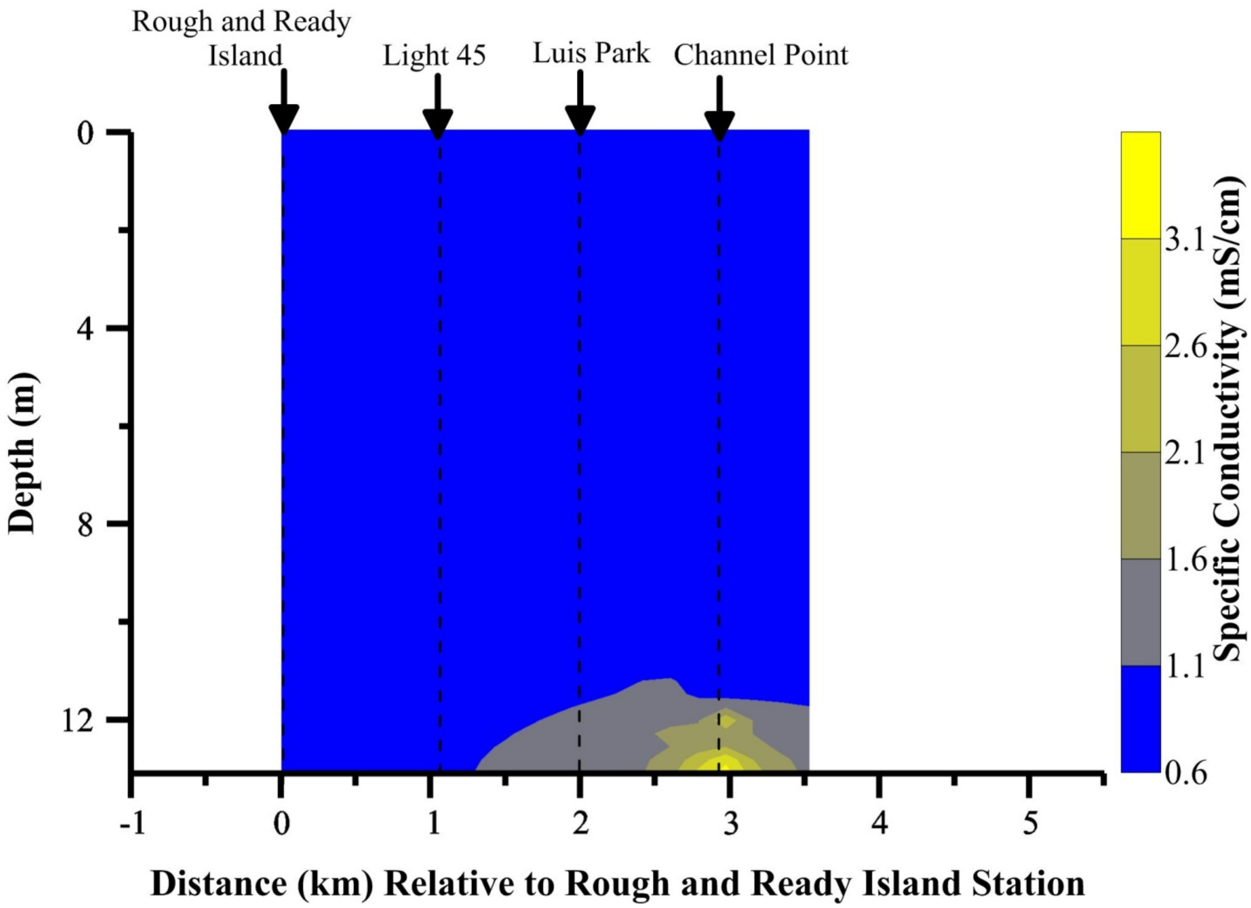

Figure 8. Contour plot of specific conductance as a function of depth and distance upstream from the Rough and Ready Island Monitoring Station on August 2, 2012.

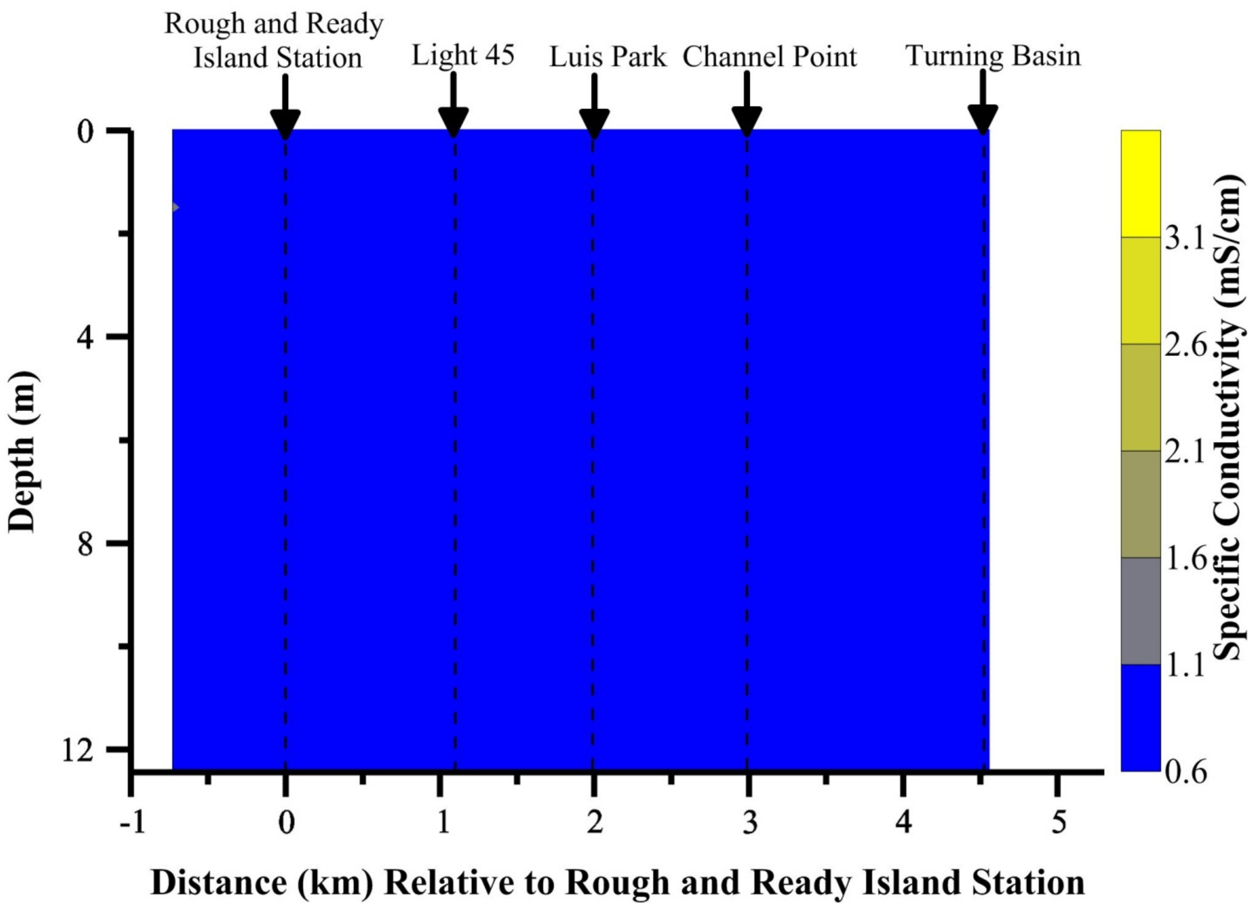

Figure 9. Contour plot of specific conductance as a function of depth and distance upstream from the Rough and Ready Island Monitoring Station on August 16, 2012.

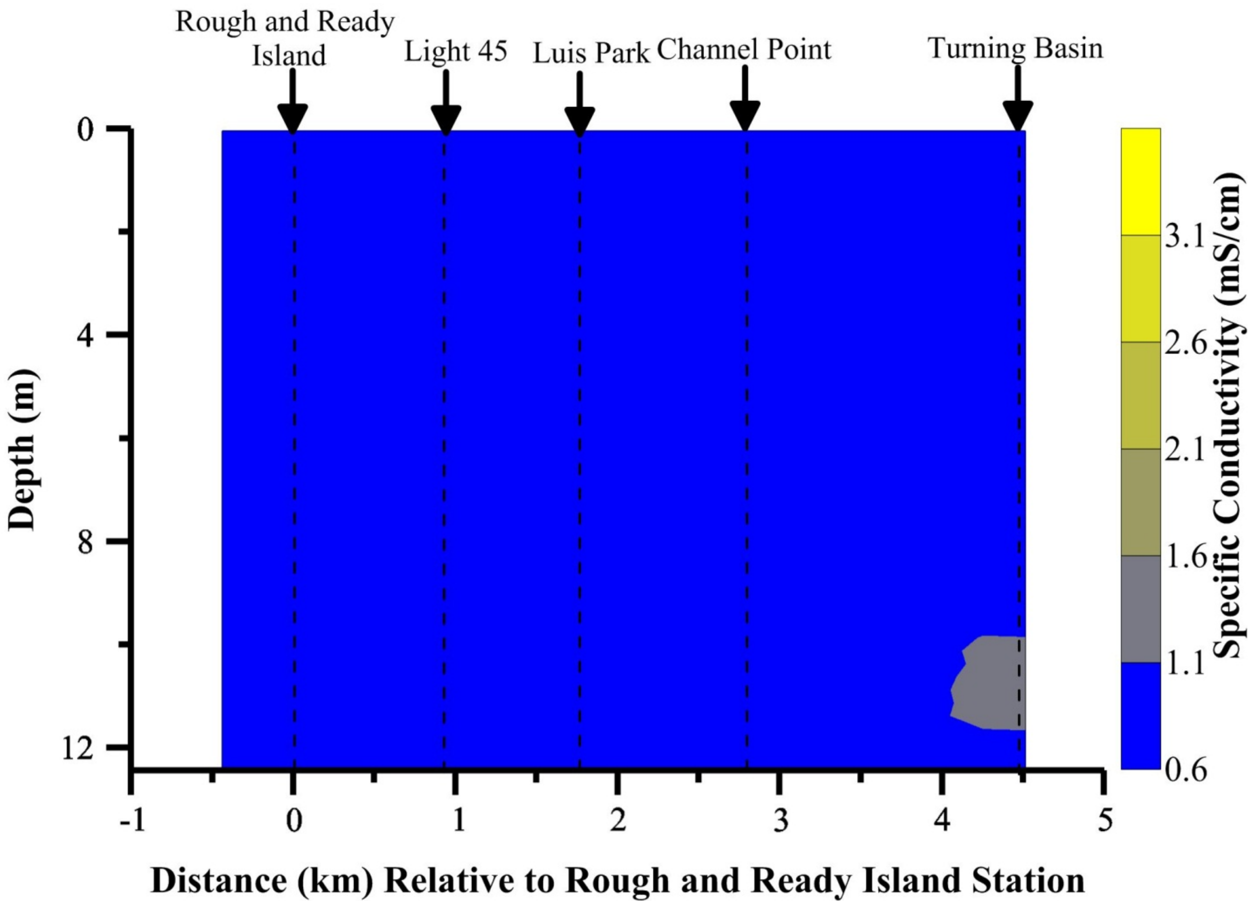

Figure 10. Contour plot of specific conductance as a function of depth and distance upstream from the Rough and Ready Island Monitoring Station on September 6, 2012.

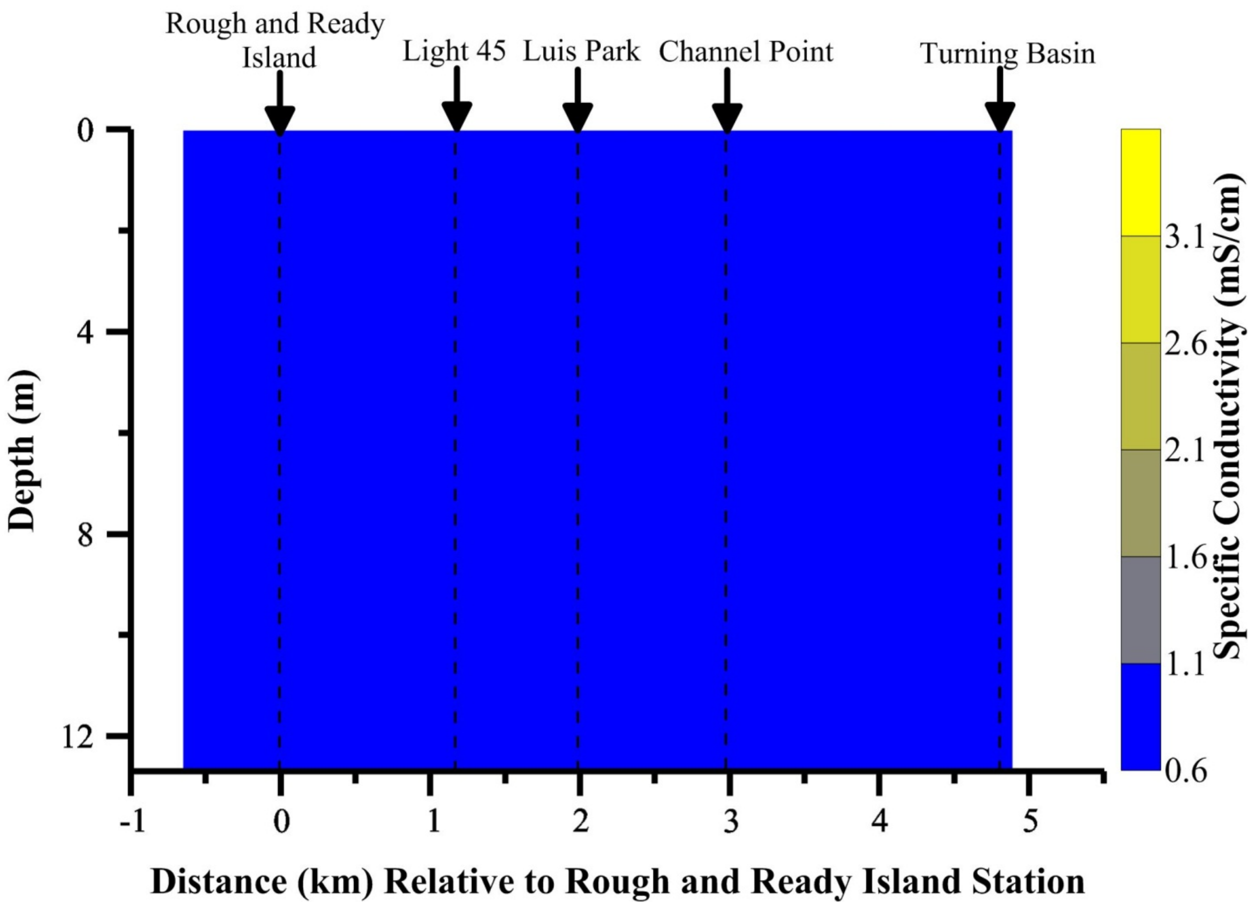

Figure 11. Specific conductance (SpC) profiles measured on July 5th 8:16am – 11:56 am, 2012 by the Ecological Engineering Research Program (EERP). Department of Water Resources (DWR) (SpC) measurements 1 m below the surface and 1 m above the river bottom measured on July 2nd 11:15am - 11:55am, 2012 for comparison.

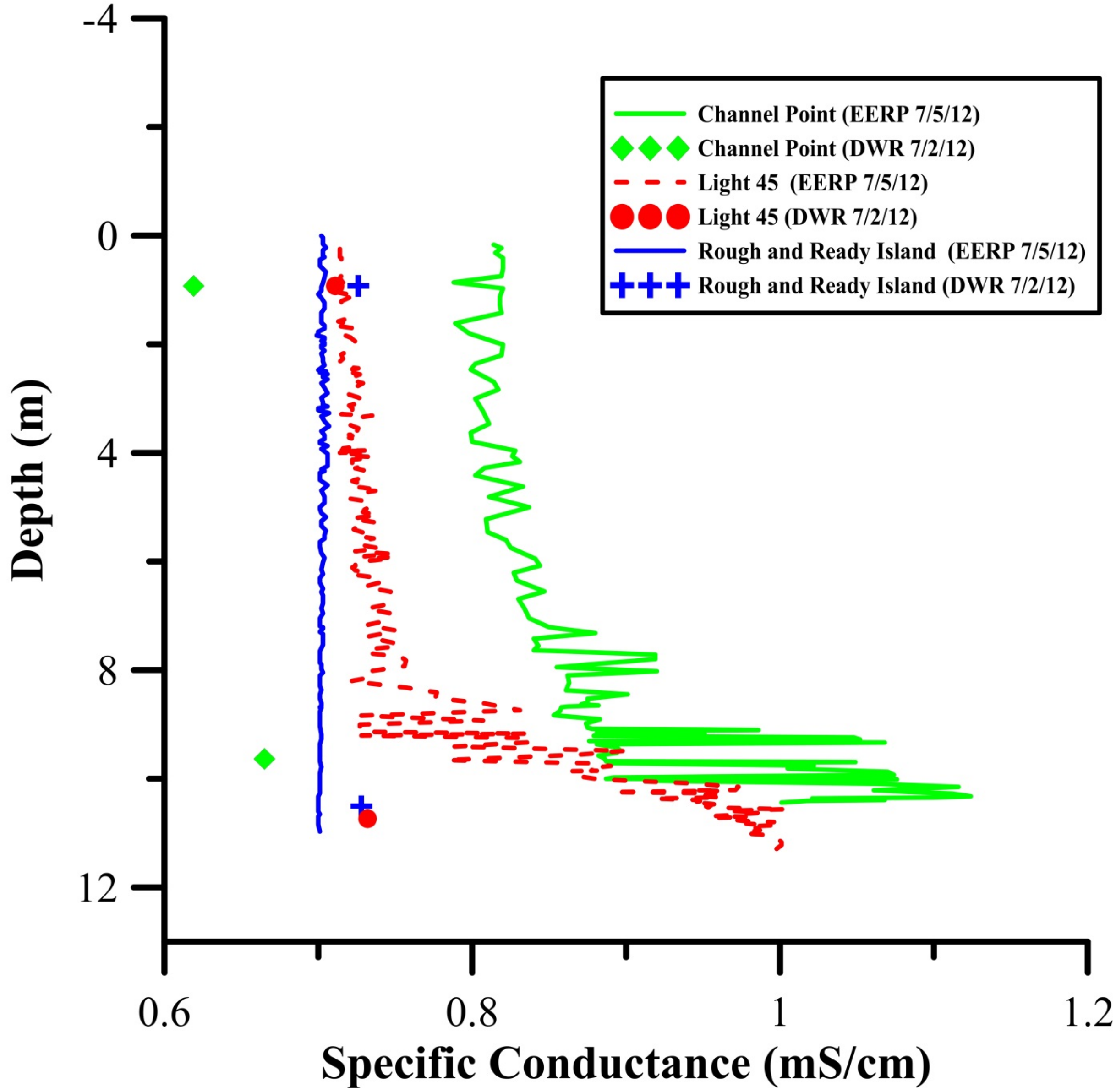

Figure 12. Specific conductance (SpC) measured on August 2nd 8:41am – 12:08pm, 2012 by the Ecological Engineering Research Program (EERP). Department of Water Resources (DWR) (SpC) measurements 1 m below the surface and 1 m above the river bottom measured on August 1st 11:15am – 12:00pm, 2012 for comparison.

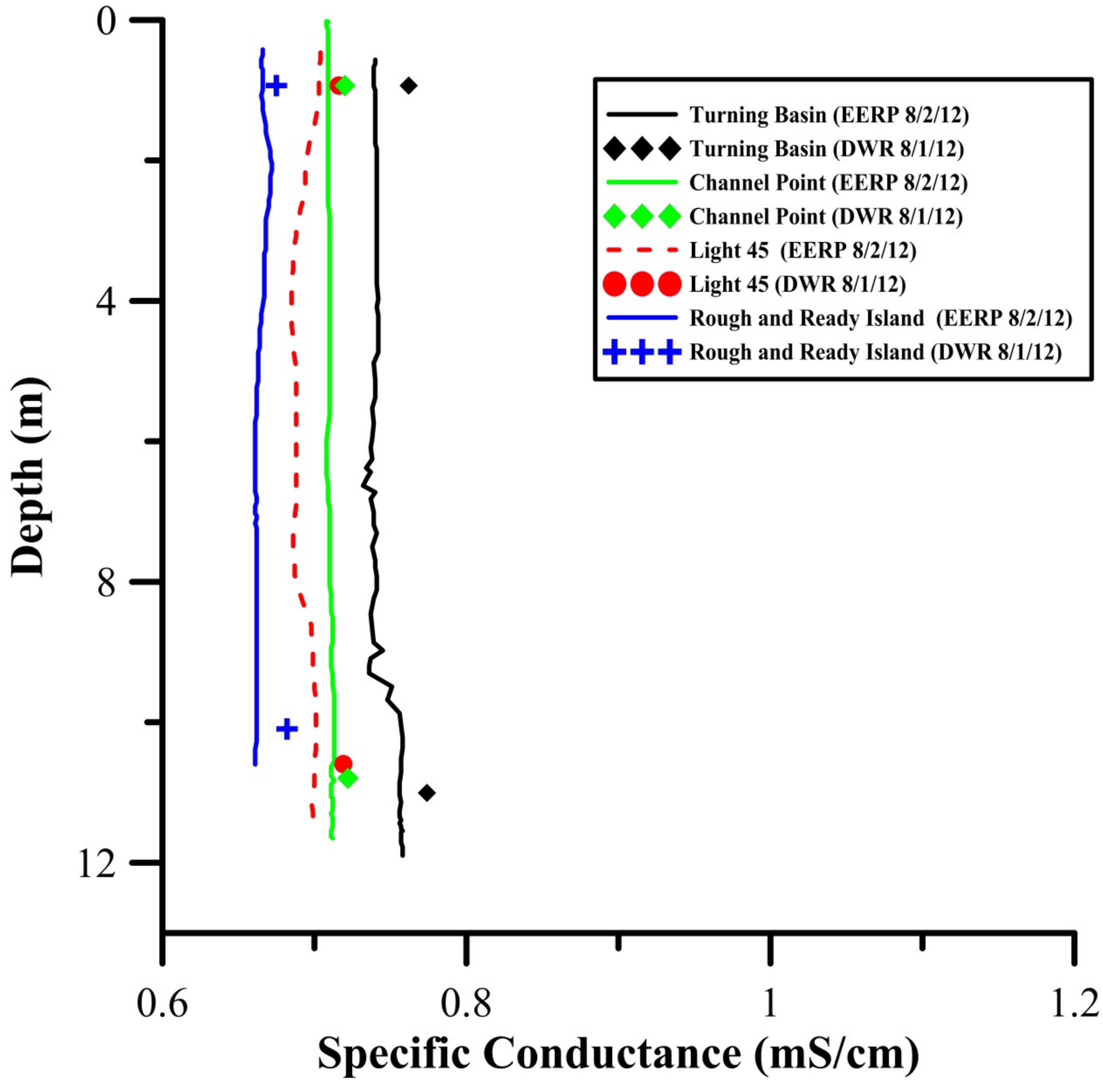

Figure 13. Specific conductance (SpC) profiles measured on August 16th 8:51am – 1:55pm, 2012 by the Ecological Engineering Research Program (EERP). Department of Water Resources (DWR) (SpC) measurements 1 m below the surface and 1 m above the river bottom measured on August 16th 11:05am – 11:45am, 2012 for comparison.

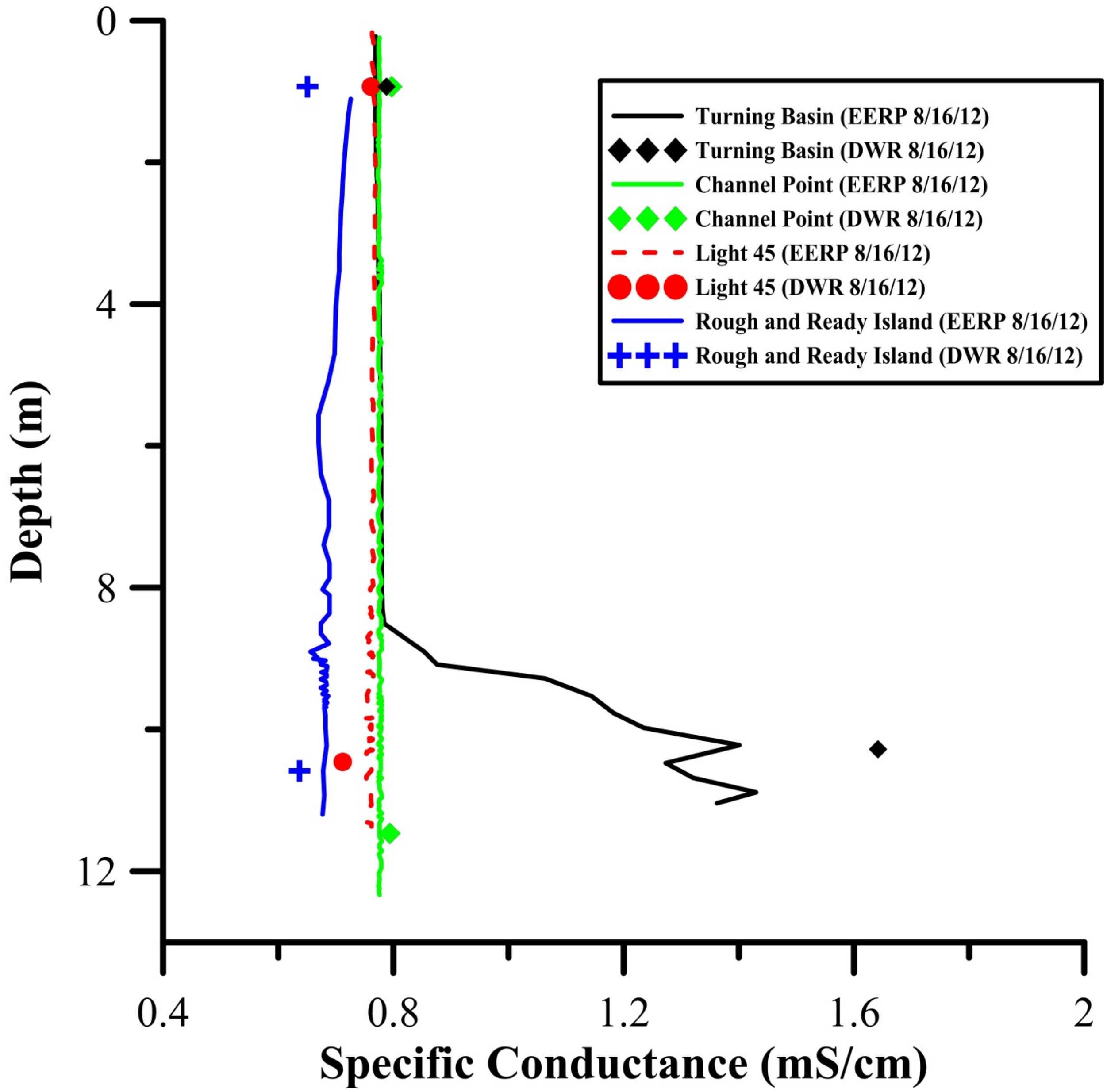

Figure 14. Specific conductance (SpC) profiles measured on September 6th 8:55am – 1:16pm, 2012 by the Ecological Engineering Research Program (EERP). Department of Water Resources (DWR) (SpC) measurements 1 m below the surface and 1 m above the river bottom measured on September 4th 1:40pm – 2:20pm, 2012 for comparison.

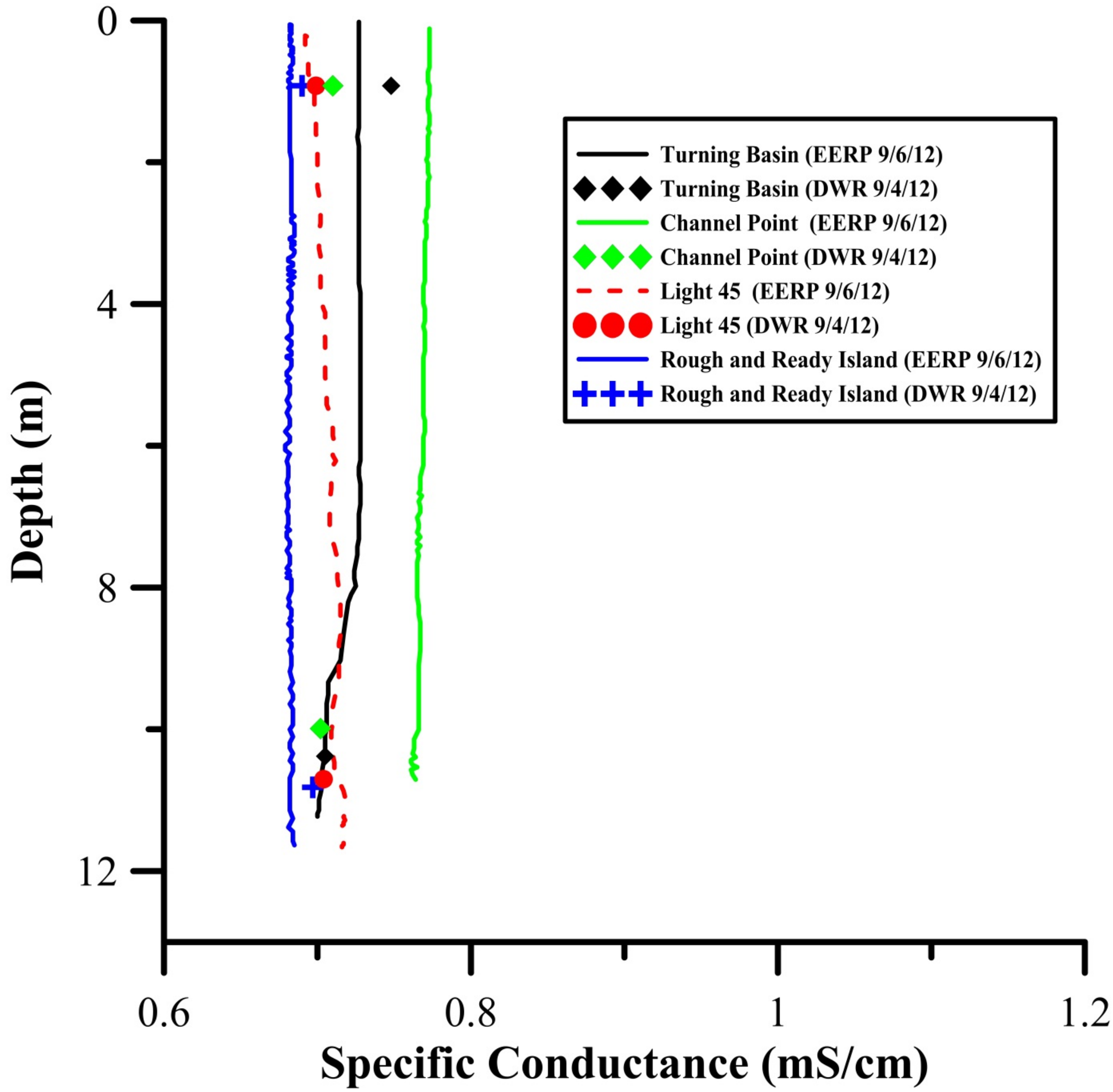

Figure 15. The Moku Pahu in port of Stockton September 6, 2012, showing listing and overboard discharge of water during loading operation.