Data Collection and Processing: Elwha Estuary Survey, February 2013

Ian Miller, WA Sea Grant

Olympic Peninsula Field Office, 1502 E. Lauridsen Blvd #82, Port Angeles, WA 98362
immiller@u.washington.edu

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Introduction

A survey of the estuary at the mouth of the Elwha River and on the Lower Elwha Klallam Tribe's reservation (Figure 1) was conducted in February 2013. The survey was conducted to track changes associated with the removal of two dams on the Elwha River. Previous surveys of this estuary complex had been conducted using a variety of methods, including manual measurements of bathymetry using a Real Time Kinematic-Differential GPS (RTK-DGPS) system. These surveys were time-consuming, and generated relatively few data for the time invested. In addition, the survey methodology introduced unquantifiable uncertainty into bathymetric measurements due to the difficulty of "feeling" the soft substrate of the estuary.

As a result, there was an interest in applying acoustic technology to collect soundings in the estuary to both increase the density of data collected and improve confidence associated with measurements. A shallow-water single beam sonar system owned by Peninsula College was applied to this problem, and coupled with a RTK-DGPS in an attempt to collect high density and high quality topography and bathymetry data in and adjacent to the estuary complex.

Figure 1. Overview map of the Elwha River delta, and the study area (red box). Image: USDA NAIP Program

Data Collection Specifications

All data for this survey were transformed to the Washington State Plane coordinate system, Washington North zone, NAD83 horizontal datum and NAVD88 vertical datum, units of US Survey feet.

Equipment

Three primary data collection platforms were utilized in this survey:

1) A Magellan ProMark 3 RTK-DGPS system, including base and rover. This system relies on nearby survey control to calculate real-time survey quality measurements of position. It was used primarily to collect topography data, as well as measure water level in the estuary relative to the NAVD88 vertical datum (Figure 2).

Figure 2. A ProMark 3 rover attached to a 6 foot rover pole being used by Daniel Bennett, LEKT, to survey the edge of the estuary complex.

2) An Ashtech ProMark200 RTK-DGPS system operating on the Washington State Reference Network (www.wsrn.org). This system was primarily used coupled to the hydrographic survey system (Figure 3), to provide real-time measurements of horizontal position.
3) A SeaFloor Systems, Inc. Sonarmite shallow water hydrographic survey system (http://www.seafloorsystems.com/sonarmite.html). This system reported raw depth returns in meters, where were converted to US Survey feet. In addition to the Sonarmite, any time that bathymetric data were being collected there was also a Horiba U-5000G multi-parameter water quality meter logging temperature and salinity data. The sensor was hung from the thwart of the canoe, typically 15 to 30 cm below the surface.

Figure 3. The Sonarmite shallow water survey system and ProMark 200 RTK-DGPS system mounted to a cata-raft.

Personnel

Personnel involved with the survey included:

4 February 2013:

- Rebecca Paradis, LEKT
- Matt Beirne, LEKT
- Ian Miller, WA Sea Grant

5 February 2013:

- Rebecca Paradis, LEKT
- Matt Beirne, LEKT
- Daniel Bennett, LEKT
- Kimberly Williams, LEKT
- Ian Miller, WA Sea Grant

8 February 2013:

- Rebecca Paradis, LEKT
- Matt Beirne, LEKT
- Ian Miller, WA Sea Grant

Methods

Day 1: 4 February 2013

The focus of day one was to test the set-up and operation of the Sonarmite system, and data were collected over just a small area of the estuary complex. Water level data were collected intermittently throughout the survey using a ProMark 3 rover mounted on a survey pole, with a local base set up on Elwha Survey Control monument 2B. Topography data were collected primarily with a ProMark 3 rover mounted on a backpack. The Sonarmite hydrographic survey system was mounted to a small cata-raft (Figure 3) and towed through parts of the estuary by canoe.

The Sonarmite system is optimally configured to output a final elevation, corrected to a particular datum, by using the RTK-DGPS output from the ProMark 200 and combining it with the soundings from the Sonarmite transducer. However, for this pilot survey the proper configuration between the ProMark 200 and the Sonarmite system was not worked out, and the output elevation couldn't be verified. As a result, a modified approach was utilized in which estuary water level was sampled on a routine basis using either RTK-DGPS or a staff gauge (Figure 4). The elevation of the bottom of the estuary, corrected to the NAVD88 vertical datum, was then derived by differencing the elevation of the water surface and each individual sounding output by the Sonarmite, after accounting for the depth of the transducer under the surface.

Figure 4. The staff gauge used to measure water level in the estuary complex on 8 February 2013.

Day 2: 5 February 2013

Day 2 was intended to comprise the bulk of the survey, with multiple individuals collecting topography with backpack and rover pole-mounted ProMark 3 units, and extensive data collection with the Sonarmite hydrographic survey system. At the end of the day, though, it was discovered that the Sonarmite system had not been properly configured, and position data from the ProMark 200 system was not recorded associated with the soundings. As a result, the bathymetric data collected on Day 2 was not valuable.

Day 3: 8 February 2013

Day 3 was focused on bathymetric soundings, to make up for the error on Day 2 that led to no valuable bathymetric data being collected. Water level data were also collected by first surveying in the elevation of a staff gauge (Figure 4) with the ProMark 200 (operating on the Washington State Reference Network [www.wsrn2.org]), and then subsequently measuring water level intermittently from the staff gauge. In the hopes of increasing sampling efficiency the Sonarmite hydrographic survey system was mounted directly to a canoe on this day (see cover photo).

Post-Processing

Topography data were trimmed to exclude water level measurements and occupations of monuments. A topography data file was produced (.xlsx) for each survey day (4 and 5 February 2013) with columns:

Pt Number	Northing	Easting	Elevation	Pt Description	Data Quality (4 columns)	Date	Time (Local)

Bathymetry data were subjected to a processing regime that included:

1) Processing the data through SonarVista with a speed of sound adjustment (to 1430 m/s)
2) Importing those data to Matlab, where a script:
    a. Converted all position data to Washington State Plane coordinates and units of feet
    b. Converted soundings from the Sonarmite system to elevations relative to NAVD88 by
        i. Matching each sounding to the interpolated water level elevation at that time
        ii. Accounting for the depth of the transducer below the surface

Data were then output to an .xlsx file, one for each survey day (4 and 8 February 2013), with columns

Northing	Easting	Elevation	Date (as a Matlab Datenum)	Sounding Quality

Results

Estuary Water Level

Estuary water level measurements were made primarily in the main body of the estuary, though on 4 February 13 measurements were collected along the edges of side channels both east and west of the main estuary pond. In general little water level variability was observed spatially – the standard deviation of all water level measurements on 4 February 2013 was 0.07 feet - so all data are plotted together here. To derive the estimated elevation of the bottom of the estuary soundings were corrected using estuary water level, and for this purpose water level measurements were interpolated to the nearest minute.

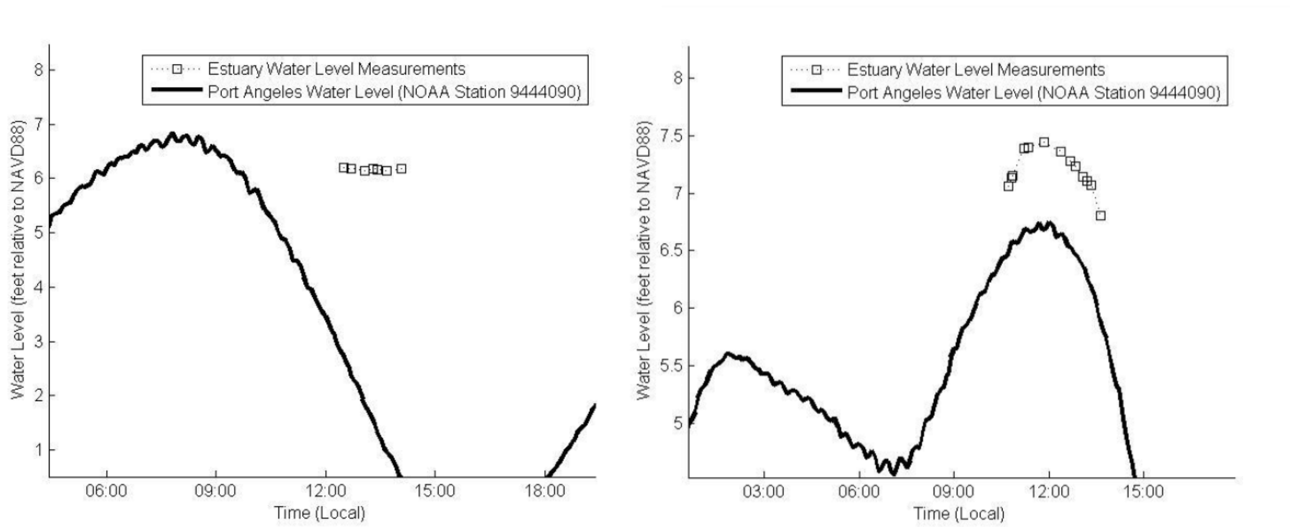

Figure 5. Estuary water level (square symbols) from 4 (left panel) and 8 (right panel) February 2013. Data are shown together with concurrent tidal water level measurements from NOAA CO-OPS Station 9444090 in Port Angeles Harbor.

Temperature and Salinity

Temperature and salinity data were collected at 30 minute intervals (approximately) using a Horiba U-5000G multi-parameter water quality sensor hung off of the side of the canoe used to navigate the Sonarmite through the estuary complex. These data were used to calculate and adjust the speed of sound setting during the bathymetry post-processing phase. The estuary was considered to be well mixed, but no temperature or salinity data were collected along a depth gradient.

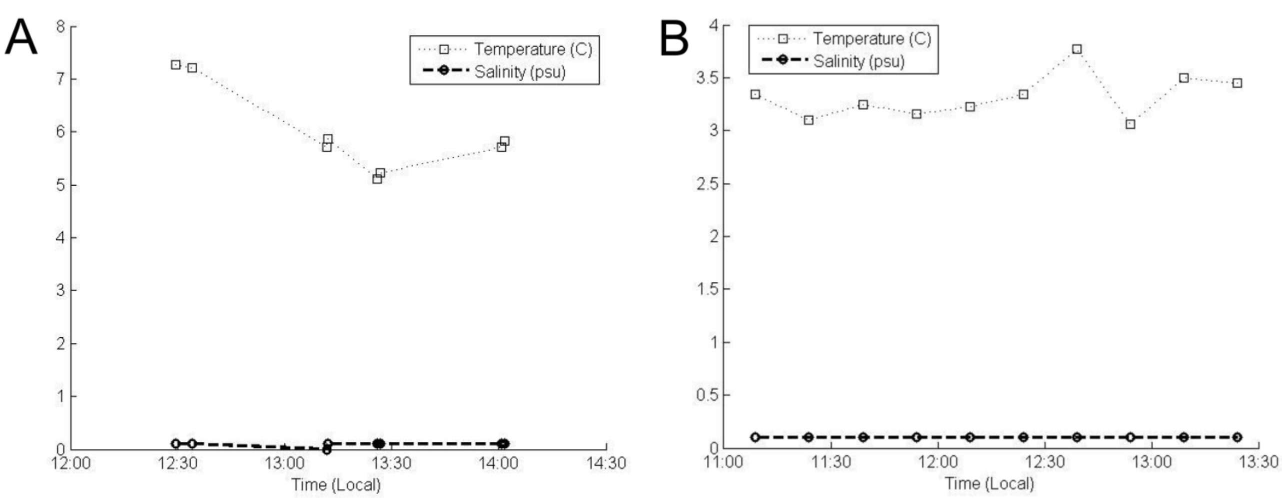

Figure 6.Water temperature and salinity time-series for both 4 February 2013 (A) and 8 February 2013 (B)

Salinity was near zero for surveys on both 4 and 8 February 2013. Temperature varied between 3 and 7.5 C (Figure 6). The speed of sound in water (using an online calculator at: http://www.es.flinders.edu.au/~mattom/Utilities/soundspeed.html) during the survey therefore varied between 1417.93 and 1443.18 m/s, and data were processed using a value of 1430 m/s. For depths of less than ~15 feet this difference in the speed of sound can generate errors of, at most, 3.5 inches (9 cm).

Topography Data

Topography data were collected by individuals either walking with a backpack-mounted logging RTK-DGPS system (Figure 7), or with the RTK-DGPS system mounted on a survey pole, and the surveyor collecting individual data points (Figure 2). All topography data were collected with the ProMark3 RTK-DGPS system, with a local base station set up on Elwha Survey Control Monument 2B using control coordinates taken from "Nearshore Monuments.Raw November 05, 2008" provided by the LEKT:

N 430706.63 ft E 974568.31 ft Elev (NAVD88): 12.94 ft

Figure 7. Rebecca Paradis, LEKT, collecting topography data with a logging RTK-DGPS system mounted on a backpack

In general topography data coverage was excellent on the north and west side of the estuary complex, but poor to the south and east (Figure 8). This was primarily due to difficulties in accessing areas to the south and east, and extensive vegetation cover that made GPS operations difficult.

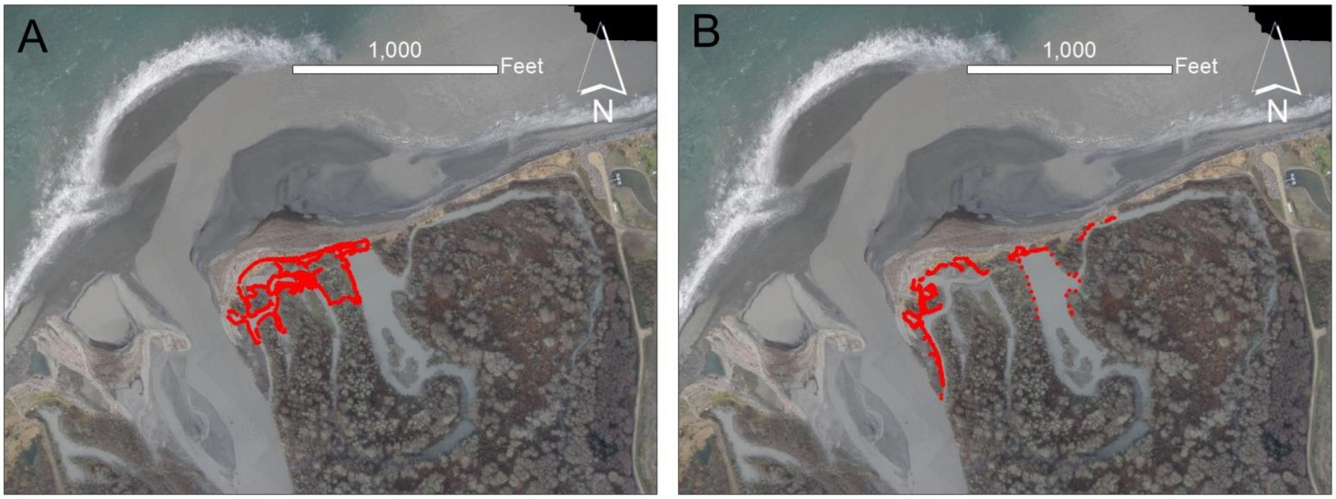

Figure 8. Topography data coverage on 4 February (A) and 5 February (B) 2013. No topography data were collected on 8 February 2013. Image: Andy Ritchie, Olympic National Park

Bathymetry Data

Bathymetry data were collected on 4 February and 8 February 2013. Data collected on 5 February 2013 did not have associated positions due to a configuration error and were discarded. Data coverage on 4 February was focused on the main pond in the estuary, and a nearby channel (Figure 9A). On 8 February 2013 the survey area was extensive (Figure 9B), covering most of the estuary complex accessible to the canoe.

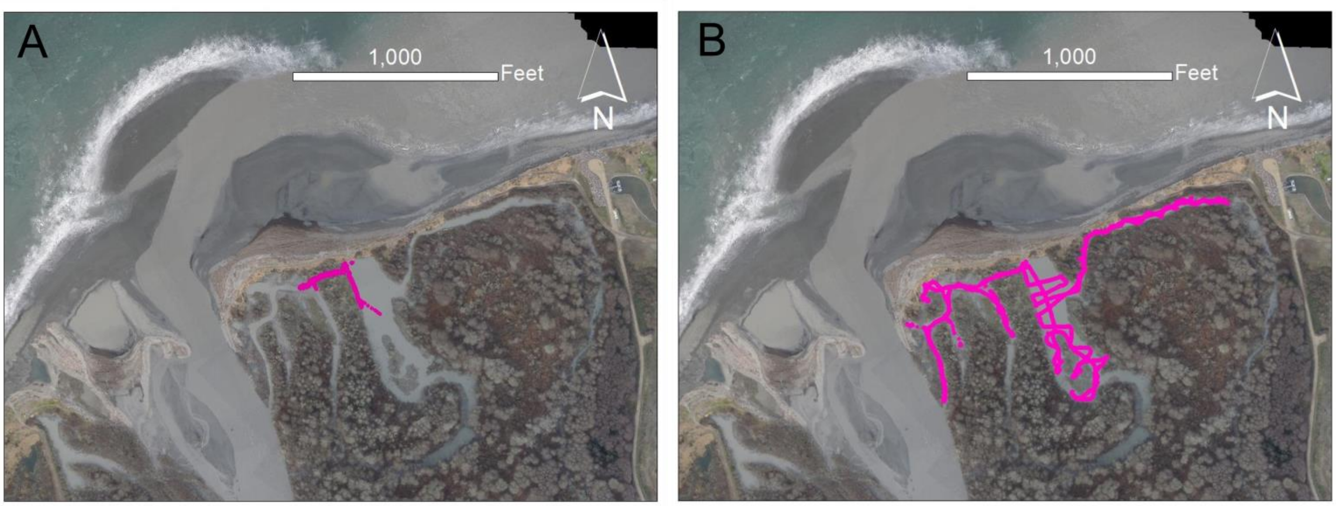

Figure 9. Bathymetry data coverage on 4 February (A) and 8 February (B) 2013. Base image from 12 February 2013 courtesy of Andy Ritchie, Olympic National Park

Combined Survey Output

The combined survey data are shown in Figure 10. Survey data are available as four separate .xlsx files (2 for topography, 2 for bathymetry) at:

https://dl.dropboxusercontent.com/u/19569402/EW_Est_Feb2013.zip

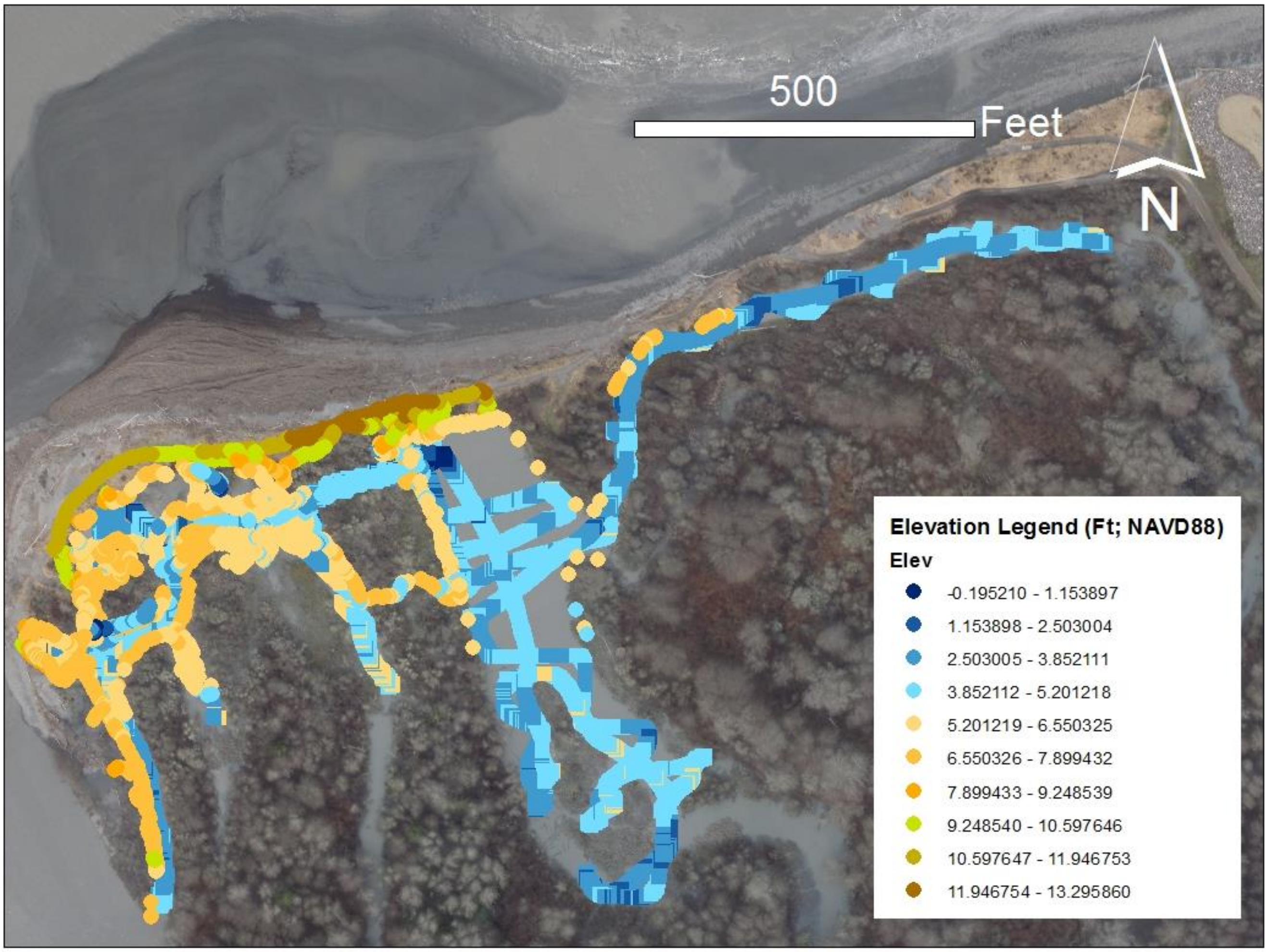

Figure 10. All topography and bathymetry data. Square symbols are bathymetry data collected with the Sonarmite hydrographic survey system and circles are topography data. Background image is from 12 February 2013 and is courtesy of Andy Ritchie, Olympic National Park

Data Quality

Survey Control

Recent re-surveys of the monuments in the Elwha Ground Control Network suggest some discrepancy (up to 3-4 inches vertically) between previously published and actual positions of those monuments. This suggests that there could be an offset between other spatial data (aerial LIDAR, for example, or positions collected with the ProMark 200 receiving corrections from the Washington State Reference Network). In this case, the control coordinates used for monument 2B throughout this survey closely match (within 0.3 ft horizontally, and 0.01 ft vertically) those provided by OPUS solutions after multiple occupations of the monument (Andrew Stevens, personal communication):

N 430706.94 ft E 974568.61 ft Elev (NAVD88) 12.93 ft

With the ProMark 3 base station set up on Monument 2B single points were collected on Monuments 2 and 2A intermittently over the course of the survey. These data were compared to control coordinates published in "Nearshore Monuments.Raw November 05, 2008". For both monuments the measured elevations deviated from the published control values by, at most, 0.08 feet (< 1 inch; Table 1). For all points collected on control monuments, the average vertical deviation from the control value was 0.00 feet, with a standard deviation of 0.04 feet.

Table 1. Summary of survey control assessment measurements made with the ProMark 3 rover, with a local base set up on Monument 2B

Monument	# of Occupations	Average Vertical Offset (ft)	Std Deviation	Minimum Offset	Maximum Offset
2A	4	0.04	0.03	0.01	0.08
2	13	-0.02	0.03	-0.07	0.03
Combined	17	0.00	0.04		

Single point occupations of Monuments 2B and 2A were made on 8 February 2013 with the ProMark 200 receiving corrections from the Washington State Reference Network. These coordinates should align well with values provided by OPUS solutions, but in this case there was a relatively large vertical offset (Table 2). The relatively small horizontal offsets, though, suggest that the error may be due to an incorrect rod height setting. The only vertical measurements made with the ProMark 200 were of water level on 8 February 2013, and these were adjusted by adding 0.25 feet to each measurement to account for this apparent error.

Table 2. Coordinates of Elwha Survey Control Network monuments estimated from a single occupation by the ProMark 200 receiving corrections from the Washington State Reference Network. Below each set of coordinates are the deviations from the best available set of OPUS solutions from long-term occupations (Andrew Stevens, USGS, personal communication).

Monument	N	E	Elev
2B	430706.90	974568.57	12.72
Deviation from OPUS	0.04	0.04	0.22
2A	430598.96	974263.47	9.67
Deviation from OPUS	0.11	0.03	0.36

Within Survey Assessment

Adjacent data from surveys on different days were used to assess survey repeatability. For topography data, any two elevations from different days (4 and 5 February 2013) that were within 1 foot (in the horizontal plane) of each other were differenced (Figure 11A). The mean difference in elevation, 0.18 feet, suggests that topography data from different days overlaps adequately. A few outliers (> 1 foot difference in elevation for points within 1 foot of each other) are expected for this survey. The steep sides of estuary channels, for example, could be expected to lead to the observed differences, especially in instances where topography points were collected on the bank and in the channel. In some cases surveyors also stumbled and/or sank into soft sediment during walking surveys, which could also lead to significant differences in elevation between adjacent points.

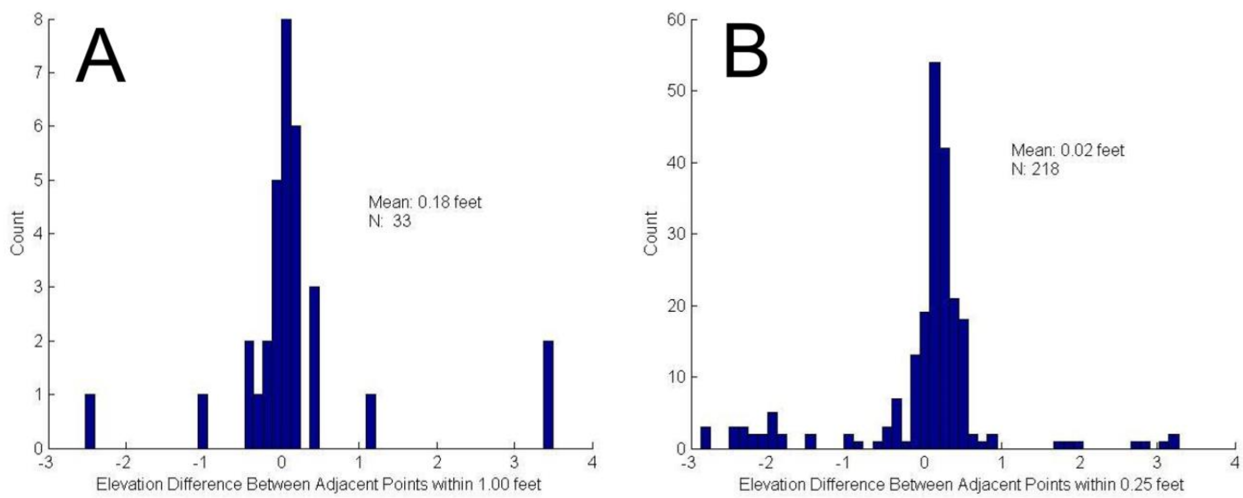

Figure 11. Elevation differences between adjacent points for topography (A) and bathymetry (B) data collected in this survey

The elevations of bathymetry data were compared for points collected on the two different days that fell within 0.25 feet of each other. In this case the mean value is 0.02 feet (Figure 11B), but with outliers that likely suggest diminished data quality for some individual points, perhaps due to rocking of the canoe (that would lead to high beam angles on the transducer), interference by vegetation or organic matter in the water, or other causes.

Given the relatively high confidence in the topography data, it is particularly instructive to look at elevation differences between adjacent topography and bathymetry data. The elevation differences between all topography and bathymetry data lying within 0.50 feet in the horizontal plane are shown in Figure 12, and the distribution is bi-modal. In general the median value, -0.21 feet (Figure 12), suggests the possibility of a small systematic offset between bathymetry and topography data. This value is within the estimated error that is possible due to speed of sound issues (see Temperature and Salinity section, above). The cluster of differences (> 2 feet; Figure 12) reflect places where topography data fell well above bathymetric readings. While these may suggest area with steep slopes, these may also be related to anomalies in the bathymetric data discussed above. It is also possible that these large offsets may reflect areas where topography data were collected by people walking in soft sediment.

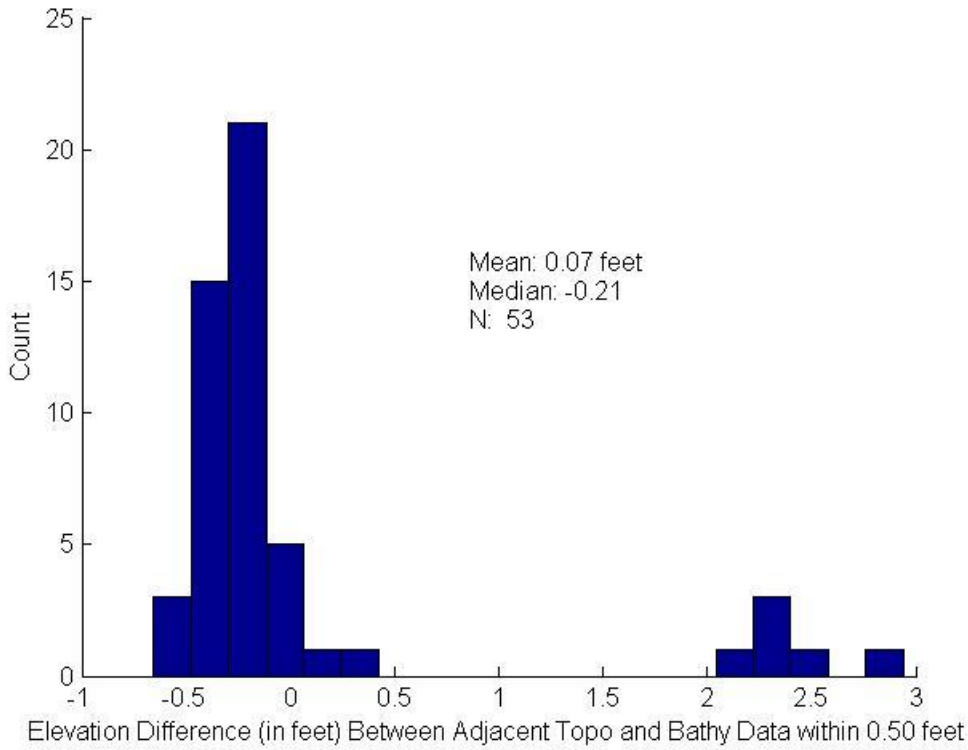

Figure 12. Elevation difference, in feet, of adjacent (within 0.5 feet in the horizontal plane) topography and bathymetry data.