Bank Topography, Bathymetry, and Current Velocity of the Lower Elwha River, Clallam County, Washington, May 2006

Data Series 363

U.S. Department of the Interior
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Cover: Photograph of the Elwha River near the mouth, Clallam County, Washington. (Photograph taken by Christopher Konrad, U.S. Geological Survey, 2006)

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Conversion Factors

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
hectare (ha)	2.471	acre
hectare (ha)	0.003861	square mile (mi^2)
	Flow rate	
centimeter per second (cm/s)	0.03281	foot per second (ft/s)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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Abstract

The removal of two dams from the mainstem of the Elwha River is expected to cause a broad range of changes to the river and nearby coastal ecosystem. The U.S. Geological Survey has documented aspects of the condition of the river to allow analysis of ecological responses to dam removal. This report documents the bank topography, river bathymetry, and current velocity data collected along the lower 0.5 kilometer of the Elwha River, May 15–17, 2006. This information supplements nearshore and beach surveys done in 2006 as part of the U.S. Geological Survey Coastal Habitats in Puget Sound program near the Elwha River delta in the Strait of Juan de Fuca, Washington.

Introduction

The Elwha and Glines Canyon dams (fig. 1) completed in 1913 and 1927, respectively, block passage of anadromous fish to most of the potential habitat in the basin and capture much of the coarse sediment load of the river (U.S. Department of the Interior and others, 1994). In 1992, the U.S. Department of the Interior was directed by the U.S. Congress to restore the Elwha River ecosystem (Public Law 102-495). By 1995, the Secretary of the Interior determined that restoration of the ecosystem required the removal of both dams (Department of the Interior, 1995). A broad range of physical and biological changes to the river, estuary, and coastal ecosystems are anticipated in response to dam removal (Munn and others, 1998). As part of the U.S. Geological Survey (USGS) Coastal Habitats in Puget Sound (CHIPS) program (Shipley and Haines, 2006), the USGS is documenting aspects of the present condition of these ecosystems to allow analysis of ecological responses to dam removal and evaluation of the effectiveness of the restoration project.

Study Area and Description

The Elwha River drains 833 km^2 of the Olympic Peninsula of Washington State (fig. 1). From its headwaters in the Olympic Mountains at an altitude of about 2,000 m, the river flows through two dams and across a coastal terrace before discharging into the Strait of Juan de Fuca. Streamflow is primarily derived from rainfall in winter months and snowmelt during spring and early summer. The Elwha Dam forms Lake Aldwell at river kilometer (RK) 7.9 and the Glines Canyon Dam forms Lake Mills at RK 21.6.

About 80 percent of the Elwha River basin is within Olympic National Park boundaries. Climate in the basin is maritime with relatively wet, mild winters and dry, cool summers. Annual precipitation in the basin ranges from about 560 cm in the upper altitudes to about 140 cm near the mouth of the river (Munn and others, 1998).

The reach of the river surveyed in this study extends from about RK 0.2 to RK 0.5 and is subject to diurnal tides from the Strait of Juan de Fuca. However, salinity measurements collected in the reach at the time of this study did not indicate the presence of saltwater (J.A. Warrick, U.S. Geological Survey, written commun., 2007). The west bank of the surveyed reach is gradually sloped and aggraded with scrub vegetation and the east bank is eroded with a moderately dense alder forest, intermittent side-channels, and snags. Channel bed material is predominantly cobbles and small boulders, with a noticeable absence of gravel-sized and finer sediment.

Purpose and Scope

This report documents the bank topography, river bathymetry, and current velocity data that were collected along a 0.3 km reach of the lower 0.5 km of the Elwha River, May 15–17, 2006. This data can be used as a baseline for measuring channel changes that will likely occur on the lower river after the dams are removed. This information also supplements nearshore and beach surveys conducted as part of the USGS CHIPS program near the Elwha River delta in the Strait of Juan de Fuca (J.A.Warrick, U.S. Geological Survey, written commun., 2007).

Figure 1. Location of the study area, Elwha and Glines Canyon dams, and river kilometers (RK) in the Elwha River basin, Clallam County, Washington. (Aerial photograph by U.S. Department of Agriculture, National Agricultural Imagery Program [NAIP], 2006.)

Methods

Bathymetric surveys of river channels and collection of current velocity data from moving boats require a means to accurately measure and record horizontal positions. Continuous Real-Time Kinematic (RTK) Global Positioning System (GPS) was coupled with an acoustic Doppler current profiler (ADCP) to measure current velocity and a single-beam echosounder to measure channel depth. The GPS elevations and echosounder depths were used to compute river-bed elevations. Similar methods were used by Barton and others (2004) for bathymetric surveying, Dinehart and Burau (2005) for streamflow velocity spatial analysis, and Conaway and Moran (2004) for the development of a hydrodynamic flow model.

Survey Control

GPS static positioning methods were used to establish survey control for this project. A GPS base station was set on a benchmark at the tribal hatchery (RTK.BASE; table 1), and referenced to two additional control points provided by the Lower Elwha Tribe (LEK.5.94 and LEK.1.95; table 1). The base station GPS relayed differential corrections to a separate roving GPS receiver that was used to determine the horizontal and vertical position of points measured by the ADCP and echosounder. Survey results were processed using the National Geodetic Survey (NGS; 2004) On-line Positioning User Service (OPUS) and transformed to Universal Transverse Mercator (UTM) North American Datum of 1983 (NAD 83) horizontal coordinates and ellipsoid heights. A geoid height model, GEOID 99, was used to convert ellipsoidal heights to North American Vertical Datum of 1988 (NAVD 88) orthometric elevations.

Two additional reference points proximal to the river channel were established using RTK-GPS: one near the mouth to set the water surface for a stage recorder (RP.2.STAGE), and one at RK 0.5 (RP.1.NAIL). The locations of control points and stage reference points are shown in table 1. The GPS device used in this survey was a Trimble 4700, for which the manufacturer reports a horizontal accuracy of ±1.2 cm and a vertical accuracy of ±2.1 cm for general performance with a baseline length (distance to base station) of 1 km (Trimble Navigation Limited, 1999).

Table 1. Location and elevation of survey control points and stage reference points, Elwha River basin, Clallam County, Washington.

[See figure 4 for site locations. Horizontal positions are in Universal Transverse Mercator (UTM) Zone 10N, North American Datum of 1983 and elevations are North American Vertical Datum of 1988 orthometric heights]

Site name	Location (meters)		Elevation (meters)
	Northing	Easting	
LEK.5.94[1]	5333189.139	458907.458	3.440
LEK.1.95	5332659.145	457774.715	4.010
RTK.BASE[1]	5332362.859	458948.071	5.079
RP.1.NAIL	5332478.558	458160.372	3.648
RP.2.STAGE	5332726.063	458039.472	1.104

[1] Sites located outside study area.

Stage

A stage sensor and a recording device were temporarily installed prior to the survey on the east bank of the river at about RK 0.2, and set to record water levels at 15-minute intervals. The stage sensor was used to monitor the tidal influence on the river during the survey. The location of the stage sensor was determined as part of the topographic survey and referenced to the water-surface elevation measured by the RTK-GPS.

Topography

Bank topography data were collected by walking over the terrain with a roving RTK-GPS receiver. Dense vegetation and tree canopy prevented positional data collection in some places, particularly on the east bank of the river. The water line at the edge of the west bank was surveyed, but otherwise no specific transect lines were followed. Instead, elevations at about 2 m spacing were surveyed to define the general topography of the bank. A single roving RTK-GPS receiver was shared between topographic and bathymetric surveys.

Bathymetry and Current Velocity

River bathymetry was measured using a single-beam, 200-kHz echosounder, and current velocity was measured with a 1,200-kHz ADCP. The echosounder and ADCP were operated independently, at times concurrently, and were interfaced with RTK-GPS. The ADCP and the echosounder were operated from a 16-ft aluminum Jon boat with a 15 horsepower propeller motor (fig. 2). The echosounder measured water depth at a rate of 1 Hz, and the ADCP measured relative water depth and current velocity (speed and direction of flow) at a single-ping rate of 2 Hz.

The ADCP transect lines were made perpendicular and parallel to the direction of flow, to map a dense data set of velocity magnitudes and directions from which longitudinal (downstream) and lateral (cross-stream) components could be defined. When used simultaneously, the echosounder and ADCP were mounted on the starboard side of the boat, with a 30 cm offset between devices. In this configuration, the RTK-GPS was mounted directly over the echosounder. When only the ADCP was used, a mapping-grade GPS with submeter accuracy (Trimble Navigation Limited, 2003) was mounted directly over the ADCP.

Figure 2. Operation of boat-mounted acoustic Doppler current profiler (ADCP) with Real-Time Kinematic-Global Positioning System (RTK-GPS), looking upstream from RK 0.5 of the Elwha River, Clallam County, Washington. (Photograph taken by Christopher Konrad, May 16, 2006.)

Results

River flow at the USGS streamflow-gaging station Elwha River at McDonald Bridge, near Port Angeles, Washington (12045500), located upstream of the study area at RK 13.8, ranged from 44.1 m^3/s to 118.5 m^3/s during the period of data collection from May 15–17, 2006 (U.S. Geological Survey, 2006). The median daily mean discharge for this gaging station ranges from 50.4 to 51 m^3/s for the same period based on 93 years of streamflow record (U.S. Geological Survey, 2008). Downstream of this gaging station, river flow may be regulated by Bureau of Reclamation operations at the Elwha Dam; however, current management practice is to allow "run of the river" or minimally regulated flows (Kevin Yancy, Bureau of Reclamation, written commun., 2008). Discharge measurements made in the Elwha River at RK 0.5 indicated an increase in discharge during the study period, but flow appeared relatively steady during the hours when bathymetry data were collected (table 2).

Water level in the river reach was influenced by a mixed semidiurnal tidal cycle, and river measurements were made during periods of low tide to minimize tidal effects. The maximum diurnal flood tide raised the water level in the reach by about 1 m above base stage during the 48-hour period (fig. 3).

Topography and Bathymetry

The topographic survey was done over 2 hours and recorded the locations and elevations of 145 points in a 2.3 hectare area, primarily on and along the cobble point bar defining the west bank of the study area (fig. 4). Surveyed elevations ranged from 0.65 m near the edge of the water to 3.37 m near the top of the point bar.

The bathymetric part of the survey consisted of measured depths and locations at 5,236 points, covering a reach of the river about 300-m long and 50-m wide. A maximum river depth of 2.50 m was measured, which corresponded to a minimum channel bed elevation of -1.13 m. The deepest part of the river channel was along the cutbank on the east side of the channel at the upstream limit of the study area. River depths were progressively shallower in the downstream direction toward the mouth and laterally toward the point bar. The extent of the survey was limited by shoaling on the west side of the channel, and by waves entering the main channel at the mouth, which caused unstable boating conditions.

Table 2. Discharge measurements at river kilometer 0.5, Elwha River, Clallam County, Washington.

[See figure 1 for site location. **Abbreviations:** m^3/s, cubic meter per second; PDT, Pacific Daylight Time]

Date	Time (PDT, 2400 hour)	Discharge (m^3/s)
May 15, 2006	19:50 – 19:51	41.9
May 16, 2006	12:34 – 12:50	83.8
May 17, 2006	11:53 – 11:59	117

Current Velocity

Channel current velocities were measured with the ADCP throughout the study reach over a 3-day period when the tidal influence on river flow was minimal. Maximum current velocities ranged from 240 cm/s at the upstream section of the reach (RK 0.5) to 160 cm/s at the section nearest the mouth (RK 0.2). Minimum operating-depth limitations of the ADCP precluded velocity measurements in channel areas that were shallower than about 0.8 m.

To improve data visualization, velocity and bathymetry data collected with the ADCP were post-processed using techniques developed by Dinehart (2003). During post-processing, outliers and bad or missing data were removed, and velocity data were smoothed through averaging. For this data set, velocities measured along similar transects were projected onto common cross sections and averaged before plotting on an aerial photograph (fig. 5). As would be expected, the highest velocities and greatest depths were measured along the outside of the bend. Secondary flow develops along river bends and is defined as flow in the cross-stream direction. Using the techniques developed by Dinehart (2003) the components of secondary flow for the averaged cross sections were computed (fig. 6). Secondary flow components were greatest in the direction from the point bar to the bank as shown in figure 6B.

Topography, bathymetry, and velocity data obtained during this survey, including information on the location and elevation of surveyed points, are provided in appendix A.

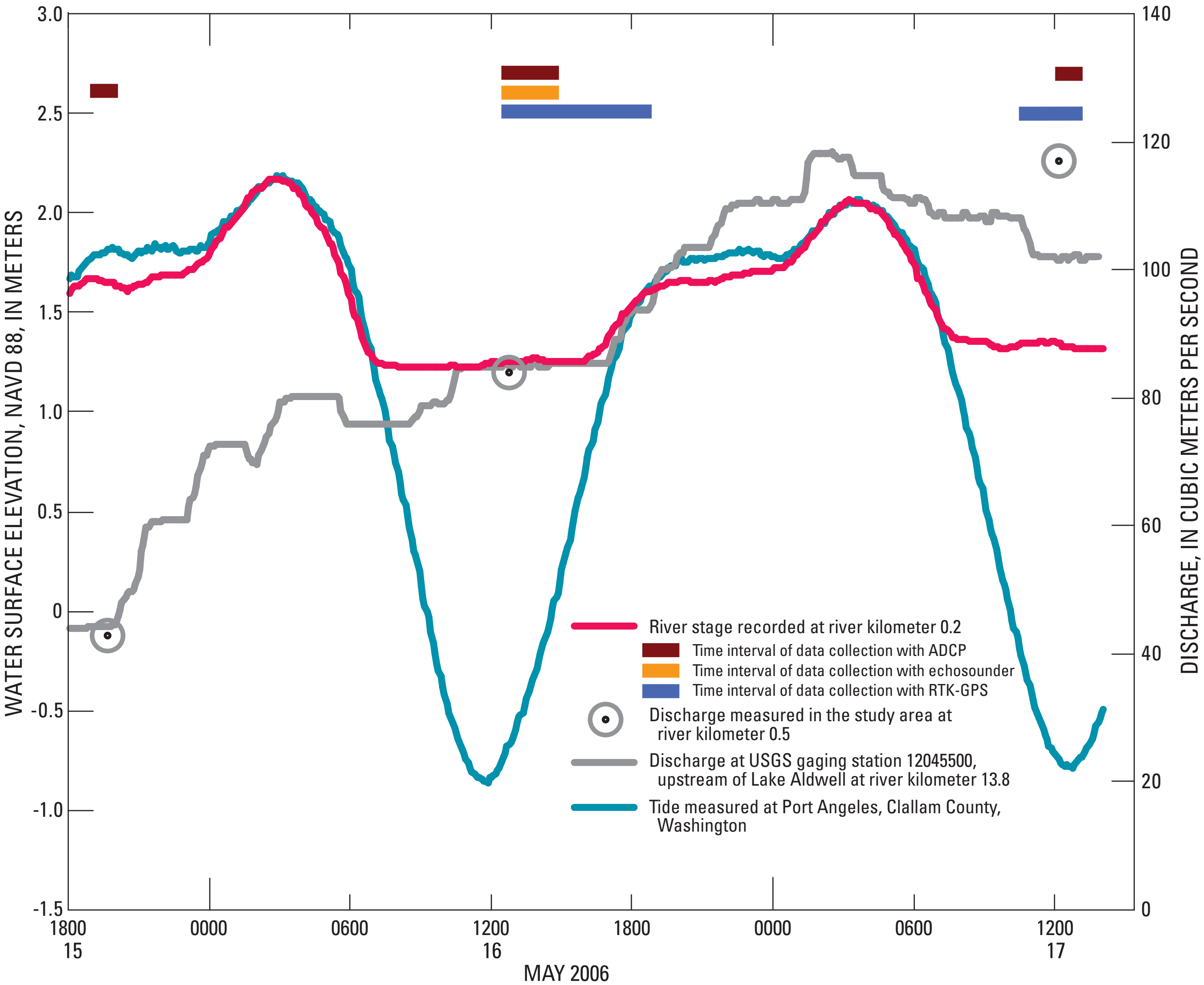

Figure 3. Water-surface elevation, discharge, and tide measurements in the lower Elwha River using various data-collection methods, Clallam County, Washington, May 15–17, 2006.

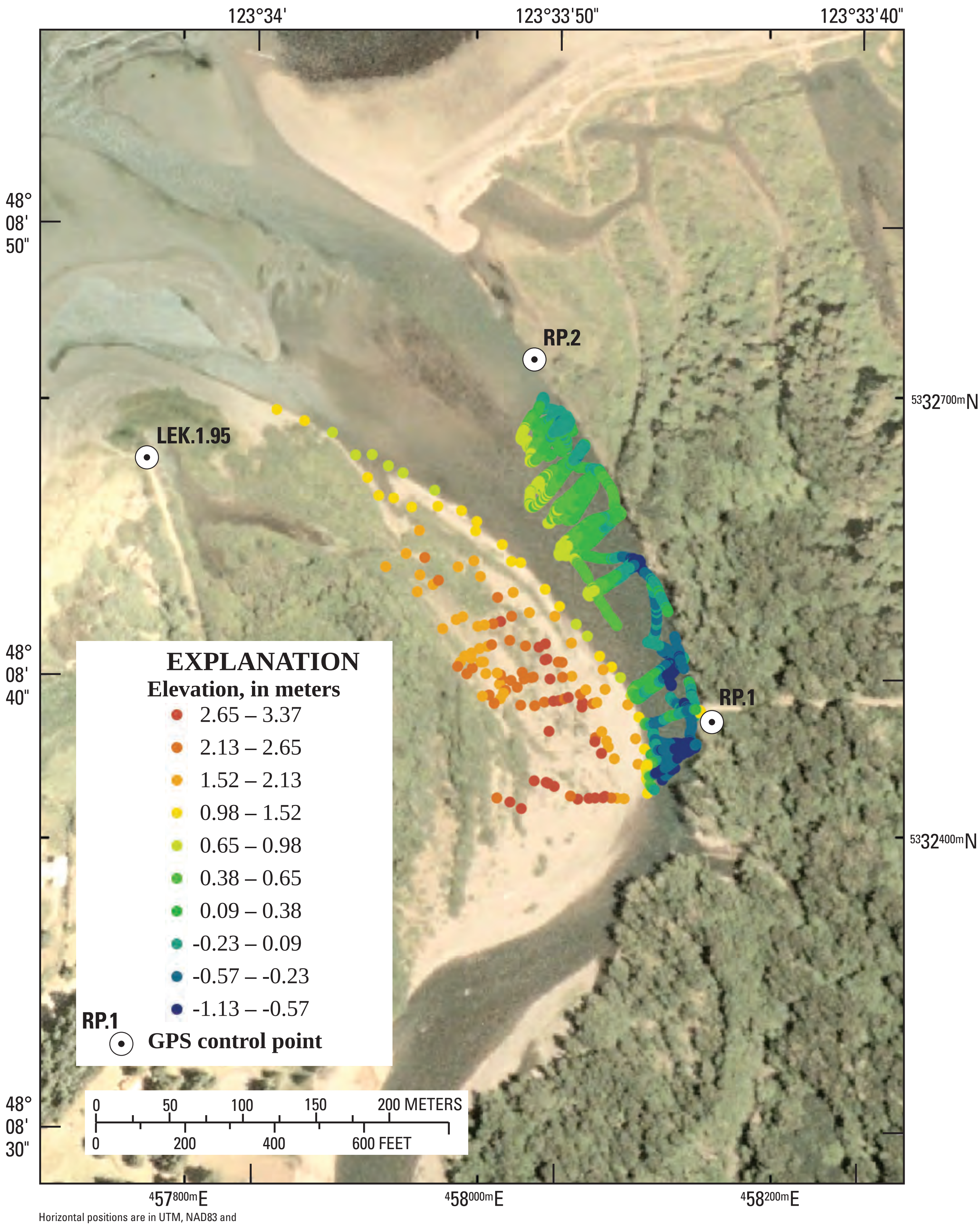

Figure 4. Elevations of points surveyed along the lower Elwha River and locations of the nearest survey control and stage reference points, Clallam County, Washington. Not all survey control points are shown. (Photograph by U.S. Department of Agriculture, National Agricultural Imagery Program [NAIP], 2006.)

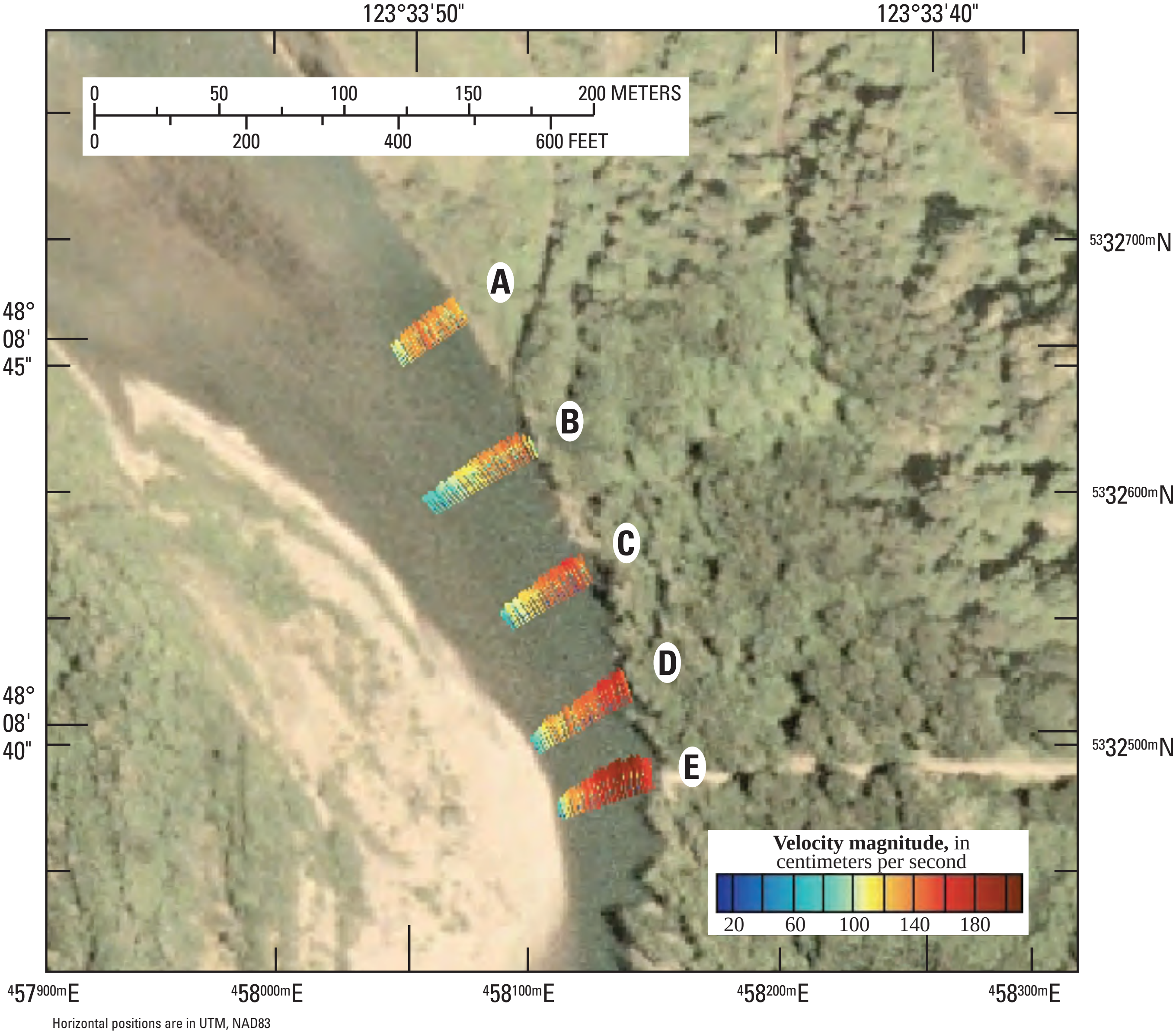

Figure 5. Plan view of projected average water velocities along cross-sections (A–E) in the lower Elwha River, Clallam County, Washington. (Photograph by U.S. Department of Agriculture, National Agricultural Imagery Program [NAIP], 2006.)

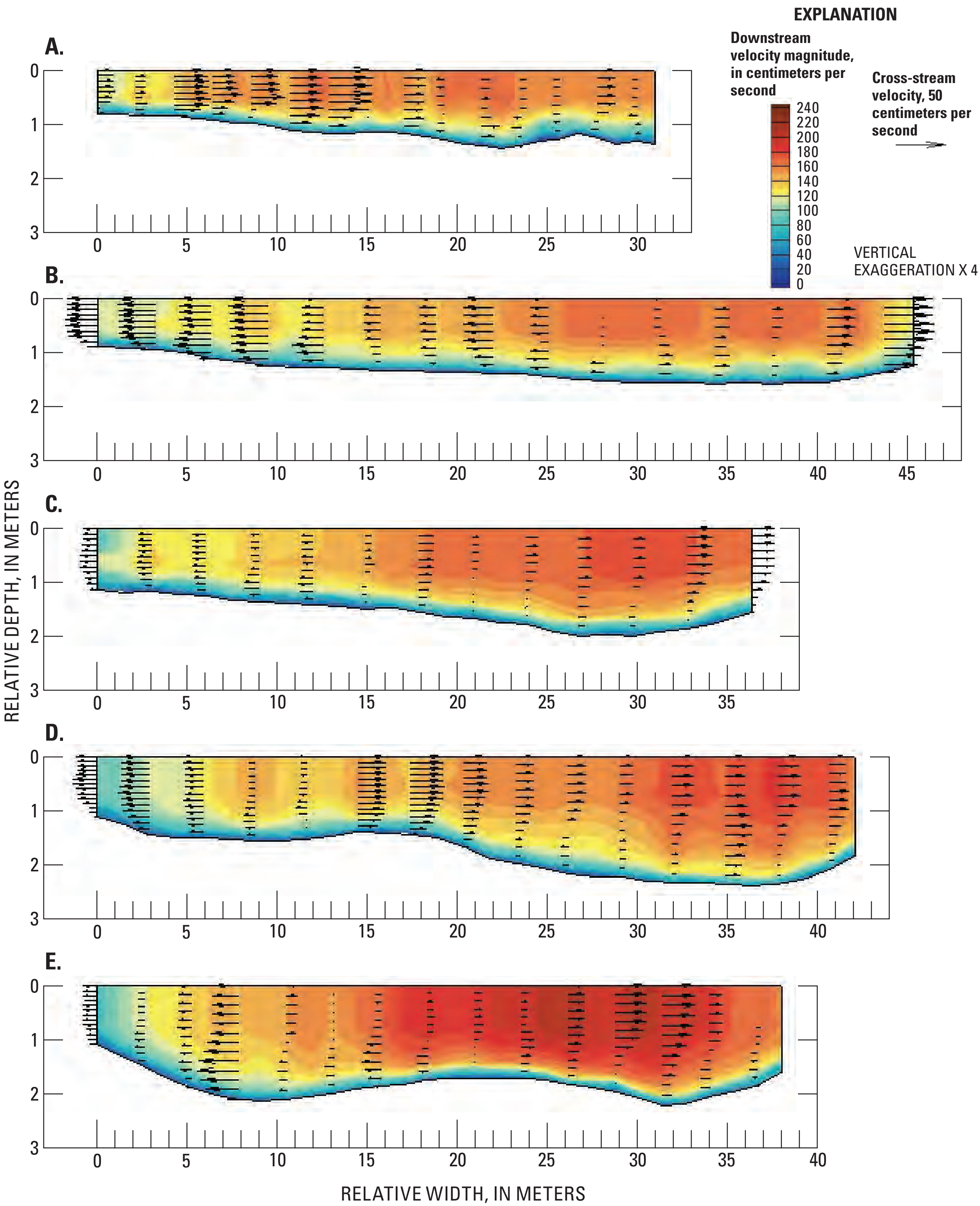

Figure 6. Water velocity in the lower Elwha River, Clallam County, Washington. Lateral, cross-stream components of velocity (black arrows) are projected onto stream-wise velocity magnitude contours. Views are downstream. Cross section locations are shown in figure 5.

Summary

Measurements of bank topography, river bathymetry, and current velocity were made along a 0.3 km reach of the lower 0.5 km of the Elwha River, Washington, during May 15–17, 2006. Measurements were made using a Real-Time Kinematic Global Positioning System to accurately measure horizontal positions, coupled with an acoustic Doppler current profiler (ADCP) and a single-beam echosounder to measure river current velocity and channel depth, respectively. This information provides a baseline for measuring channel changes following dam removal and supplements nearshore and beach surveys conducted as part of the U.S. Geological Survey Coastal Habitats in Puget Sound program near the Elwha River delta in the Strait of Juan de Fuca.

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Appendix A. Data Format and Access

Microsoft® Excel spreadsheets containing information on the location and elevation of surveyed points are available for downloading. ADCP transect files containing current velocity and relative channel depths are available in Excel files generated using AdMap software (D.S. Mueller, U.S. Geological Survey, written commun., 2007).

Table A1. Acoustic Doppler current profiler data summary, lower Elwha River, Clallam County, Washington, May 2006. Data are available at http://pubs.usgs.gov/ds/363/DS363_TableA1.xls

Table A2. Combined bathymetry and topography, lower Elwha River, Clallam County, Washington, May 2006. Data are available at http://pubs.usgs.gov/ds/363/DS363_TableA2.xls

Table A3. Acoustic Doppler current profiler data, lower Elwha River, Clallam County, Washington, May 15, 2006. Data are available at http://pubs.usgs.gov/ds/363/DS363_TableA3.xls

Table A4. Acoustic Doppler current profiler data, lower Elwha River, Clallam County, Washington, May 16, 2006. Data are available at http://pubs.usgs.gov/ds/363/DS363_TableA4.xls

Table A5. Acoustic Doppler current profiler data, lower Elwha River, Clallam County, Washington, May 17, 2006. Data are available at http://pubs.usgs.gov/ds/363/DS363_TableA5.xls

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