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Bathymetry of the Hong and Luoc River Junction, Red River Delta, Vietnam, 2010

By

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Abstract

The U.S. Geological Survey, in collaboration with the Water Resources University in Hanoi, Vietnam, conducted a bathymetric survey of the junction of the Hong and Luoc Rivers. The survey was done to characterize the channel morphology of this delta distributary network and provide input for hydrodynamic and sediment transport models. The survey was carried out in December 2010 using a boat-mounted multibeam echo sounder integrated with a global positioning system. A bathymetric map of the Hong and Luoc River junction was produced which was referenced to the datum of the Trieu Duong tide gage on the Luoc River.

Basemap from ESRI , 2009, World Imagery, and regional insert from ESRI accessed Sept. 2012 at *http://www.esri.com/software/arcgis/arcgis-online-map-and-geoservices/map-services*

Figure 1. Location of the junction of the Hong and Luoc Rivers, Red River delta.

Luoc River. Photograph by Yasuyuki Shimizu, 2010.

Sand barge, Hong River. Photograph by Paul Kinzel, 2010.

Trieu Duong tide gage. Photograph by Yasuyuki Shimizu, 2010.

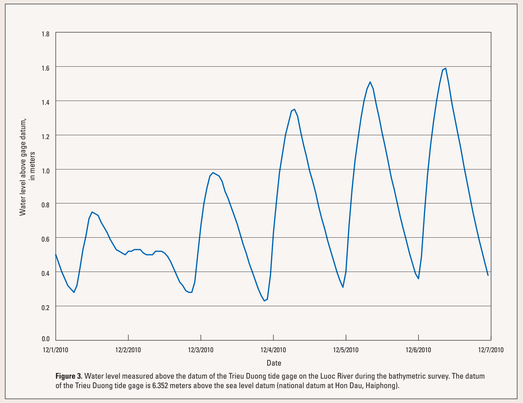

Figure 3. Water level measured above the datum of the Trieu Duong tide gage on the Luoc River during the bathymetric survey. The datum of the Trieu Duong tide gage is 6.352 meters above the sea level datum (national datum at Hon Dau, Haiphong).

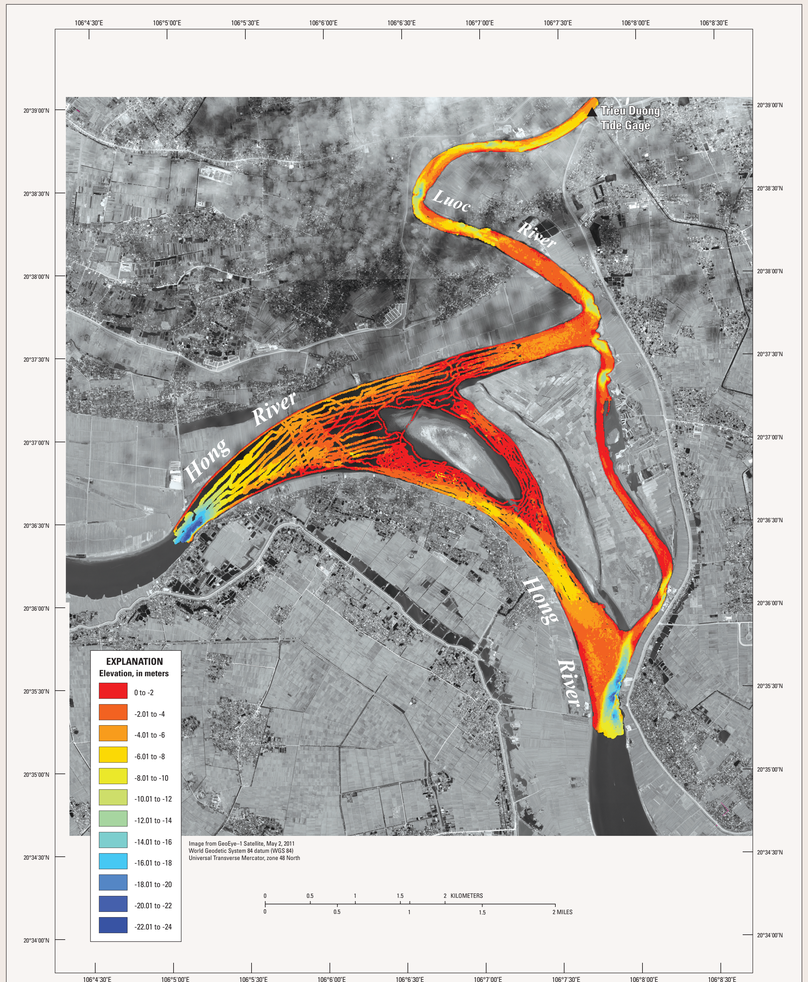

Figure 2. Bathymetry of the Hong and Luoc River Junction relative to the datum of the Trieu Duong tide gage on the Luoc River, December 1–6, 2010. The bathymetry is overlain on a panchromatic image taken May 2, 2011 with the GeoEye–1 satellite.

Hong River. Photograph by Yasuyuki Shimizu, 2010.

Bank of the Hong River. Photograph by Yasuyuki Shimizu, 2010.

Introduction

Deltas are formed where a river empties into a larger body of water such as an ocean, lake, reservoir, or estuary. The dynamics of streamflow and sediment transport at this interface promotes the deposition and accumulation of sediments. These sediment deposits can provide fertile soils that support cultivation; many large river deltas are densely populated (Binachi and Allison, 2009; Syvitski and others, 2009).

The vulnerability of coastal deltas to climate change and specifically the effects of sea level rise has recently become a global concern. In 2007, the International Panel on Climate Change (IPCC) identified Vietnam as a country that will be influenced by rising sea levels; for a 1 meter rise in sea level 5,000 square kilometers (km^2) of the Red River delta, and 15,000 –20,000 km^2 of the Mekong River delta are projected to be flooded (Cruz and others, 2007). Upstream dams are also a concern as they can reduce the sediment supplied to river deltas and their network of distributary channels.

As a first step in understanding the hydrodynamics and sediment dynamics of delta distributary channels, the U.S. Geological Survey (USGS) in collaboration with the Water Resources University in Hanoi, carried out a bathymetric survey of the Hong and Luoc River junction, Red River delta, Vietnam, in 2010. These data were collected to provide input for modeling software to simulate the mechanics of streamflow and sediment transport in river deltas (Nelson and others, 2011). The bathymetric survey also provides baseline conditions (2010) for river managers concerned with flooding, sedimentation, bank erosion, and navigational issues at this complex channel bifurcation.

The purpose of this report is to describe the data collection, processing, and editing methods used in the bathymetric survey of the junction of the Hong and Luoc Rivers. A bathymetric map referenced to the zero gage datum of the Trieu Duong tide gage on the Luoc River is also presented.

Description of Study Area

The Hong River, or Red River, originates in China where it is referred to as the Yuan River. It flows into northern Vietnam and then southeast through the capital city of Hanoi to the Gulf of Tonkin (fig. 1). The river is named for the color imparted to the water from suspended silt that is rich in iron oxide. The survey site is in Hung Yen Province near the city of Hung Yen located approximately 50 kilometers (km) southeast of Hanoi. The bathymetric survey included the junction of the Hong and Luoc Rivers and the reaches of each river extending from the junction (fig. 2). The Luoc River is a distributary channel that receives water from an upstream bifurcation of the Hong River and flows to the Gulf of Tonkin. The flow in the Luoc River can be influenced by the pattern of streamflow routing at the junction with the Hong River (Nelson and others, 2011).

The survey area is located within the Red River delta, a region dominated by rice cultivation and integral to the agricultural economy of Vietnam. Rice production in the delta was 6.6 million tons in 2000, 20 percent of the production of the entire country (Bo and others, 2003). In addition to water supply for agriculture, the river is a source of sediment that is exploited as raw material for the local construction industry.

The annual discharge of the Red River has been estimated to be 137 × 109 cubic meters (m^3) of water per year and 116 × 106 tons of suspended sediment per year (Pruszak and others, 2005). The hydrologic regime of the region can be separated into a wet season from June to October and a dry season from November to May (Phong and others, 2005). The variability in these seasons is further illustrated by Phong and others, 2005:

> "In low discharge season, the water level at Ha Noi hydrological station averages for [sic] 3.50 meters (m). The discharge varies between 900 and 2,770 cubic meters per second (m^3/s). In high discharge season, the monthly discharges vary between 4,120 and 8,990 m^3/s and water levels at Ha Noi average for 7.12 m. The peak recorded flow of 34,200 m^3/s occurred in 1971, when water level reached 14.02 m."

Historically the seasonal nature of river flows in the Red River delta influenced the settlement of people in this region (Masanari, 2007). Levee systems were built after the 10th century to provide communities and agricultural land protection from floodwaters.

Bathymetric Survey

The bathymetric survey was conducted December 1–6, 2010 using an Odom ES3PT-M multibeam echosounder with a Trimble SPS461 Global Positioning System (GPS) receiver. The Omnistar HP service was enabled on the GPS receiver to gain access to the APSAT (Asia Pacific SATellite) network and provided real-time differential GPS positioning. Omnistar reports that the HP service usually has a 2-sigma (95 percent) horizontal error of about 6 centimeters and a 99 percent horizontal error of less than 10 centimeters (*http://www.omnistar.com/about.html*, accessed Dec. 1, 2011). The HP service operates using the ITRF (International Terrestrial Reference Frame) 2005 datum. The GPS receiver also provided the heading or direction of travel of the boat.

The Teledyne Odom ES3PT-M multibeam echosounder operates at a frequency of 240 kHz and emits 240 sonar beams over a swath width of 120 degrees (Teledyne Odom Hydrographic, 2011). A motion reference unit (MRU) measures the precise pitch, roll, and heave of the sonar and is mounted directly behind the sonar head, a design that eliminates offsets with the sonar. The pitch is defined as the angle of the mounted system with respect to a horizontal plane passing through the boat and parallel to the water line, the roll is the angle with respect to a vertical plane oriented perpendicular to the water line, and the heave is defined as the vertical translation of the system with respect to the water line. A sound velocity sensor is mounted near the sonar head to measure the speed of sound which is critical for the received beam to be formed correctly. Data streams from the GPS (position and heading), MRU, sound velocity sensor, and sonar were integrated and processed with a computer running the HYPACK hydrographic survey software (HYPACK, Inc., 2011). A secondary computer controlled the sonar and the range, and gain settings were continuously adjusted to maintain consistent reflections from the bottom.

The multibeam system was mounted on the survey boat, tested, and calibrated on December 1, 2010. The calibration involved determining the precise pitch, roll, and yaw angle (yaw is defined as the deviation with respect to the axis of the boat along the keel) offsets of the mounted system; this process is commonly referred to as a patch test. The angular offsets measured for pitch, roll, and yaw were -1.0, 0.2, and -4.0 degrees, respectively.

Since the speed of sound varies with water temperature, pressure, and salinity, and this speed is used in the sonar ray-bending calculations, it was necessary to make measurements of the speed of sound through the water column. A Teledyne Odom Digibar-Pro profiling sound velocimeter (Teledyne Odom Hydrographic, 2001) was lowered and raised through the water column and measured the sound velocity at 0.5-meter increments. The sound velocity casts were transferred and used in the HYPACK software. Sound velocity casts were made periodically throughout the survey to check and confirm the reproducibility of the profiles.

It was also necessary to account for the influence of tides during the bathymetric survey. The Trieu Duong tide gage on the Luoc River (fig. 2) was operated continuously during the survey and recorded hourly measurements that were used to adjust the sounder depths to the zero datum of the gage. The tide values were obtained by the Water Resources University from the Trieu Duong hydrologic gage and are shown in figure 3.

Hydrographic surveys within the HYPACK software can be planned to ensure the efficient collection of bathymetric points at a given grid resolution. Once the grid or matrix was selected, the hydrographic survey software provided a real-time map showing the matrix cells that had been traversed by the sonar and also those that were yet to be traversed. Fine resolution matrices (1 × 1 m) were used to ensure high spatial resolution in regions of high topographic relief such as dune fields or scour holes, while coarser resolution matrices up to 10 m were used in regions where such detail was not needed.

Data Processing

A bathymetric map of the surveyed areas was produced in World Geodetic System 84 datum (WGS 84), Universal Transverse Mercator (UTM) zone 48 North projection, and referenced to the zero datum of the Trieu Duong tide gage located on the Luoc River. The depths measured during the survey were corrected for the tidal influence measured at the Trieu Duong tide gage on the Luoc River using a tide file in the HYPACK software. Prior to processing, the offsets for the multibeam system were entered as well as the angular corrections determined by the patch test. The multibeam data was manually edited to remove obvious outliers caused by erroneous sonar returns. The bathymetric points collected in the study area were then resampled to a 5 × 5 m grid. Each point in the grid is the average depth of all soundings collected in a 5 × 5 m area or cell. The location of each point is the center of the grid cell. Figure 2 shows the distribution of soundings that were mapped to the 5 × 5 m grid and are expressed as elevations relative to the zero gage datum of the Trieu Duong tide gage.

Summary

The U.S. Geological Survey, in cooperation with the Water Resources University in Hanoi, conducted a bathymetric survey of the Hong and Luoc River junction in Hung Yen Provence, Vietnam, from December 1– 6, 2010. The survey was completed with a multibeam echosounder equipped with a real-time differential GPS for boat positioning and navigation. A bathymetric map was produced from the surveyed data in a geographic projection and was referenced to the zero datum of the Trieu Duong tide gage located on the Luoc River.

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Luoc River near Trieu Duong tide gage. Photograph by Yasuyuki Shimizu, 2010.

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Multiply	By	To obtain
meters (m)	3.281	feet (ft)
cubic meters (m^3)	35.31	cubic foot (ft^3)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
kilometers (km)	0.6214	miles (mi)
square kilometer (km^2)	0.3861	square mile (mi^2)

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