



## A geospatial tool for delineating streambanks

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### ABSTRACT

Ecologists, civil engineers, and conservation managers currently lack an automated software tool for delineating streambanks, which is an important input for various hydrological studies. Therefore, a computational method for automatically delineating streambanks using aerial imagery and stream centerline datasets was developed and incorporated in a stand-alone, user-friendly desktop-based geospatial tool. This interactive tool, titled Streambank Delineator (StreBanD), was tested on the 161-km Lower White River and 158-km L'Anguille River in Eastern Arkansas using 1-m resolution 3-band aerial imagery and National Hydrography Dataset Plus (NHDPlus) stream centerline. The near-infrared band and normalized difference water index (NDWI) were evaluated for feasibility of streambank delineation. Results showed that the NDWI, a multi-band index approach, consistently provided superior delineations when compared to the single band (near-infrared) approach especially for complex channel morphologies, including braided channels and meandering segments, in the L'Anguille River. The geospatial tool successfully delineated the streambanks for both rivers in less than 10 min with a mean error ranging from 0.3 m to 10.3 m when compared with five manually delineated streambanks. Due to the generic and simple nature of this tool, it should assist scientists and conservationists in rapidly delineating streambanks for their study areas.

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### Software availability

Software name: StreBanD

Year first available: 2011

Software required: Matlab component libraries v7.16 on PC

Programming language: Matlab

Availability: Contact the second author to obtain this software and user manual

Cost: Free

### 1. Introduction

The identification and mapping of streambanks is of fundamental importance to ecologists and conservationists who focus on riparian buffers (Day and Brooks, 1997), channel erosion and scouring (Abernethy and Rutherford, 2001), and to civil engineers with interest in flood plain mapping (Poole et al., 2002). Streambanks can generally be defined as the physical interface between land and water during bankfull stage of the waterbody (Lawler,

1993). This definition, however, can be difficult to apply because the location of streambanks can change continually through time due to various anthropogenic and environmental factors. Hence, streambanks need to be monitored temporally and consistently during bankfull discharge period in order to assess the impact of various human (Murgatroyd and Ternan, 1983) and natural (Poff et al., 1997) factors. A repeatable mapping methodology is thus required to quantify external impacts on streambanks.

Field-based surveying was traditionally practiced to acquire geographical location of streambanks along several transects. While this methodology is accurate, it can be time consuming and laborious. Advancements in geographical information systems (GISs) software and availability of remote sensing datasets offers immense scope for delineation of transition zones, such as aquatic–terrestrial interfaces (Johnston and Bonde, 1989; Fortin et al., 2000). For instance, using aerial photos as a base layer, human interpreters can easily delineate streambanks in a GIS. However, this manual process can again get laborious when the water body extends for several kilometers. In addition, the subjectivity of human interpretation of streambanks makes this method non-repeatable.

The alternative approach has been to use geospatial techniques to automate the streambank delineation process (Lawler, 1993;

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Hughes et al., 2006). Remotely sensed spectral raster data acquired during bankfull discharge period can be used, for instance, to identify those pixels in an image that represent streambanks; this technique being typically called image classification. The image processing literature has several examples of applications of classification techniques, which can be broadly classified into supervised and unsupervised (Schowengerdt, 2007). Supervised classification, in general, requires the manual identification of a known surface feature within the imagery. The spectral fingerprint of the identified surface feature is then used to classify the remainder of the image. Supervised classification is an attractive option when features of interest are previously known. Several natural features have been delineated using supervised classification techniques for various environmental modeling and monitoring purposes (Schowengerdt, 2007).

Streambank delineation, however, poses unique challenges when applying the supervised classification technique. Streambanks are interfaces between aquatic and terrestrial features and can be best-represented using lines. Line features are stored in a vector format in a GIS using a shapefile. To apply supervised image classification techniques for streambank delineation, the output (i.e. the classified raster) needs to be converted to a vector format. For instance, Merwade (2007) used small buffers created around a stream centerline as training areas for converting aerial, remotely sensed images into water and non-water classes using supervised classification. The areas classified as water were subjected to raster and vector GIS operations to delineate river and lake boundaries. Though this method was successful in delineating boundaries of rivers, it had three shortcomings: (1) conversion of GIS data from one format to another format introduces error (Wade et al., 2003), (2) training samples used for supervised classification are influenced by site-specific data, and (3) land surfaces adjacent to the stream can also contain water, rice fields for example, which may be classified inaccurately as water and hence requires tedious post-processing.

While comparing vector and raster-based methods for environmental assessments, Wade et al. (2003) observed that vector-based methods generally result in accurate results while raster-based methods are generally faster. To overcome the limitations of the methodology reported by Merwade (2007), there is a need to develop a computational method that incorporates information from available vector and raster datasets and rapidly delineates accurate streambanks. In addition, the method has to be generic so that it can be easily applied to multiple study areas. Computer-based tools provide a convenient and user-friendly way to apply new methods to diverse study areas (Zhang and Srinivasan, 2010; Pai et al., 2012). Currently, there are no such methods or customized software available to scientists and conservationists to delineate streambanks using available geospatial datasets.

Further, error analysis is considered an important component for any computational method so that the user can get a sense of the uncertainty involved in the results. Errors involved in output from computational methods are commonly acknowledged but seldom considered while analyzing results. While reviewing the issues involved with boundary detection techniques, Fortin et al. (2000) stated that little attention is being paid to develop error measures for resulting segmentations. In fact, examples of error analysis in boundary detection studies in the literature are sparse. Two exceptions were the works of Merwade (2007) and Lee et al. (2009). Merwade (2007) compared the area of water pixels identified by his algorithm against the area of a manually delineated polygon encompassing the stream boundary. However, this approach ignores the directionality of errors. Considering that the algorithm overestimated the streambank at some locations

and underestimated at others (see Fig. 8 in Merwade, 2007), this area-based method could potentially cancel out errors and provide unreliable estimates of error. Lee et al. (2009) used light detection and ranging (LIDAR) measurements for determining coastal shoreline, and evaluated results by manually delineating the shoreline at three sections and measuring the perpendicular distance to the automatically delineated shoreline at several points in a GIS environment. The results were presented as root mean square error (RMSE) of distances between the two curves. This is a superior evaluation method compared to Merwade (2007) since it accounts for directionality, albeit the manual measurement of perpendicular distances are prone to human errors and can get tedious when evaluating at several locations. Hence, there is a need to advance this method by providing an automatic and quantitative technique for assessing accuracy of streambank delineation.

Our overall goal for this study was to improve the current streambank delineation technology. This goal was accomplished through three specific objectives:

1. developing a computational method for rapidly delineating streambanks using existing vector and raster geospatial datasets,
2. implementing the developed method in a stand-alone user-friendly graphical user interface tool, and
3. comparing the output from the software with manually delineated streambanks to perform error analysis.

The rest of the paper is organized into six sections. Section 2 includes discussion on development of a computation method that uses vector and raster geospatial datasets to delineate streambanks (Objective 1). Section 3 explains the incorporation of the computational method in a desktop-based software titled StreBanD (Objective 2). Section 4 includes discussion on approach used for quantifying errors (Objective 3). Section 5 discusses evaluation of StreBanD in two rivers in Arkansas with contrasting channel morphologies. Section 6 includes discussion on limitations of StreBanD, and Section 7 contains summary of key results and identification of potential for future work.

## 2. Streambank delineation method

A computational method for creating left and right streambanks is presented in this paper using the stream centerline vector dataset from the National Hydrography Dataset Plus (NHDPlus) and 1-m resolution multi-spectral raster imagery. These vector and raster datasets provide critical and complementary information to the proposed method while ensuring speed and accuracy. All geospatial datasets used were projected to the Universal Transverse Mercator (UTM; Zone 15 N) projection with North American Datum of 1983 (NAD83) geographical coordinate system. The method was developed in MatLab (MATLAB, 2010) programming environment using various functions and routines from the Mapping and Curve Fitting toolboxes. The working of this method has been illustrated using a flowchart in Fig. 1 and discussed below.

First, the NHDPlus dataset (1:24,000 scale) was manually edited in a GIS, wherever found necessary, so that it is positioned over the water body and the results were visually verified at 1:1000 scale using 1-m resolution natural color imagery. The proposed method only requires the centerline data to be on the water body; not necessarily passing through the center of the water body. While the NHDPlus dataset was expected to fall on the water body by default, deviation from the waterbody at several stream sections were found; therefore, preprocessing of the NHDPlus dataset to ensure correct location of stream centerline over natural color imagery was performed.

The NHDPlus centerline was available in a common GIS file format namely, shapefile. This shapefile contained the latitude and longitude of centerline node points along the water body. MatLab's "shaperead.m" function, which is part of the Mapping toolbox, was used to read latitude and longitude of each node point. A cubic spline was fit to these nodes along the latitude, and along the longitude, using the Curve Fitting toolbox. Then, a first order derivative was taken and evaluated at each node, which represents a tangent vector to the curve at that node using the following equation (Fig. 2; Schwartz et al., 1960):

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