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A MOBILE GEOGRAPHIC INFORMATION SYSTEM TO SUPPORT STREAM IDENTIFICATION

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ABSTRACT: Riparian buffer protection rules that apply to select river basins in North Carolina require field identification of the origins of intermittent and perennial streams. Stream evaluations by consultants and state agency personnel utilize geomorphologic, hydrologic, and biologic indicators in a point-ranking format. Paper forms used in the stream evaluations are subject to transcription errors and require additional efforts to transfer the collected information into a database for analysis of data. Geographic information technology was applied to create a distributed information system for recording, analyzing, and presenting stream types and locations for riparian buffer applications. Stream evaluation data can be input into a digital version of the data form via the GIS interface or office software suites. A mobile GIS application for field data input was developed utilizing off-the-shelf-technology to integrate GPS and touch–screen hand held computer hardware. Spatial and attribute data from the mobile application were then seamlessly integrated with the geodatabase maintained on an Oracle database. Under certain environments, geographic data can be transmitted to the hand held application using broadband wireless technology. Use of the mobile hydrologic information system has reduced the time and cost associated with entering stream evaluation data into computer applications and making that data available to interested agencies. The database schema for the storage of stream origin and stream network features is forward compatible with both the Arc Hydro and the NHD geodatabase models. KEY TERMS: stream identification, stream types, mobile GIS,

INTRODUCTION

Three stream types, ephemeral, intermittent, and perennial have typically been defined in accordance with annual flow duration or flow duration plus water sources (e.g., Hansen 2001, Hewlett 1928, Mosley and McKercher 1993, Satterlund and Adams 1992). Standards for the National Hydrography Dataset specify two stream types. Perennial streams contain water throughout the year, except for periods of extreme drought. Intermittent streams contain water for only part of the year, but more than just after rainstorms and at snowmelt (USGS 1999a, USGS 1999b). For purposes of Clean Water Act Section 404 permits, the Army Corps of Engineers defines intermittent and perennial streams in terms of flow duration and groundwater contribution to flow (DACE 2002). For application of riparian buffer rules, the State of North Carolina developed definitions for the three stream types that refer to geomorphologic, hydrologic, and biologic character (State of NC 2000).

Various methods have been utilized by private, state, and federal agencies for the field determination of intermittent and perennial stream origins. The USGS in Massachusetts used a logistic regression procedure to predict the probability of a stream being perennial or intermittent based on drainage area, drainage density, mean basin slope, percent of stratified drift deposits, and basin location (Bent and Archfield 2002). Sveca et al. (2005) made the distinction between perennial and intermittent flow based on watershed area, width-to-depth ratio, entrenchment ratio, and stream channel slope gradient. In a study in the Northwest Cascades mountains, most headwater streams were considered to be intermittent if they lay within 100 m of the channel head (Veldhuisen 2004), and a 21 acre drainage area represented a minimum threshold for a perennial stream (Veldhuisen 2000). In the Southern Appalachians, Rivenbark and Jackson (2004) used drainage area and channel width to define perennial flow. In North Carolina, the NC Division of Water Quality (NCDWQ) and other NC state agencies utilize a methodology with 29 ranked indicators covering geomorphologic, hydrologic, and biologic characteristics to assist in the field identification of intermittent and perennial stream origins. In addition, the state of North Carolina uses benthic macroinvertebrate assessment as an option for identifying perennial stream origins (NCDWQ 2005).

For the purpose of identifying the location of stream channels, "blue lines" depicted on USGS topographic maps, are commonly used. However, the poor positional accuracy of stream network locations depicted on these maps reduce the effectiveness of these sources for use in accurately determining intermittent and perennial stream break points (Morisawa 1957; Gandolfi and Bischetti 1997; Heine et al. 2004). Advances in computing technology have provided some solutions to the challenge of finding and classifying streams for regulatory purposes. Geographic Information Systems (GIS) have been

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utilized to generate predicted locations of stream networks (Fairfield and Leymarie 1991). Still newer advances, such as digital elevation models derived from Light Detection And Ranging (LIDAR) data, provide highly accurate topographic representations which further increase the accuracy of modeled stream networks (Restrepo and Waisanen 2004). The availability of low cost Personal Digital Assistants (PDA) and small footprint GPS receivers has led to a variety of hand held mobile GIS platforms that can record positional information and various spatial attributes in a robust and mobile configuration. Recent applications in mobile GIS have ranged from: 1) developing a handheld platform to locate airport pavement distress (Huang et al. 2005); 2) delineating lithostratigraphic structures in the field (Briner et al. 1999); 3) publishing spatial data to field devices utilizing wireless networks (Vivoni and Camilli 2003; Casademont et al. 2004); 4) viewing satellite imagery of real time position while in transition across the terrain (Dobson 2001); 5) writing positional data to digital photographs (Spinellis 2003); 6) supporting archeological surveys (Ancona et al. 1999); 7) teaching students scientific field procedures (Armstrong and Bennett 2005); and 8) guiding blind pedestrians (Golledge et al. 1998).

As mobile technology permeates the scientific community, some traditional limitations have been alleviated while new ones must still be overcome. For example, as wireless hardware achieves exponential gains in throughput, battery technology has not kept pace with wireless power consumption resulting in less operating time in wireless environments (Simunic 2005). Physical constraints such as battery life, combined with the effects of environmental conditions such as rain and heat on hardware limit the usefulness of mobile devices in harsh and remote locations (Fong et al. 2003). However, the convenience of having a mobile, field ready solution outweighs these limitations.

The ease with which spatial data collected with heterogeneous mobile platforms can be shared among decision makers and server platforms highlights the issue of semantic interoperability of data schema (Harvey et al. 1999). Development of a mobile GIS platforms requires a comprehensive understanding of the data to be collected and the semantics of how the data will be used by decision makers (Pundt 2002). These constraints have been satisfied in a mobile GIS platform supporting geological field mapping (Brodaric 2004). The FieldLog application developed by Brodaric (2004) utilizes a design that incorporates interoperability between the user interface on the mobile device and the database that stores the data. Such standardization allows for ease of use of the mobile system and the ability to perform analysis of the data without the need to modify data dictionaries.

Described here are the hardware and software components of a mobile stream identification GIS platform that records positional and attribute information associated with the identification and location of intermittent and perennial stream origins in North Carolina. The client side architecture incorporates the 29 characteristics used by NCDWQ to identify stream origins in the field and classify stream origin type (NCDWQ 2005). Spatial information can be wirelessly transmitted or manually uploaded to an enterprise database system where the data are accessible to decision makers and a variety of software tools.

METHODS

The principle requirement of the stream identification mobile GIS is that information pertaining to the 29 indicators of stream origin type is written to a point feature class along with a unique identifier for the point and positional information. The handheld component consists of a Hewlett Packard IPAQ 5150 running Windows Pocket PC 2003. ESRI's ArcPad 7 was installed and configured to interface with an external global positioning system (GPS) source. ArcPad is a scaled down version of ESRI ArcMap and is designed to run on mobile devices with minimal hardware requirements. Besides serving as an interface for collecting spatial data, basic editing and base map functions also exist in ArcPad. The IPAQ is contained within a ruggedized and waterproof case proprietary to the IPAQ 5100 series of PDAs. The system was designed to interface with a mapping grade Leica GS50 GPS system via a serial data cable but has also been successfully deployed with GPS units that output the standard NMEA GPS transmission protocol via Bluetooth wireless connectivity.

During the course of this study the IPAQ was also successfully interfaced with several recreational type GPS units such as Garmin and Magellan. However, due to the proprietary nature of pin assignments for serial connections, significant variations were found among models by different manufacturers which required a separate cable for each device. Through trial and error it was discovered that it was best to attach a stand alone Bluetooth transmitter to the GPS device, thus eliminating the need to maintain lengthy cables which tended to have limited service life while operating in rough environmental conditions. When using backpack type GPS systems, with real time correction capability and a Bluetooth antenna to send NMEA signals to the handheld device, this configuration allowed for the positioning of the GPS device at a stationary location. By using a soil auger as a GPS mount, further flexibility was provided for movement throughout the stream origin area observing and recording stream attributes on the hand held device while the GPS unit continued to record data.

To make stream type and origin determinations for riparian buffer rule applications, NCDWQ employees utilize a three-section form to assign a point value to each of 29 geomorphologic, hydrologic, and biologic characteristics of the stream being surveyed (Table 1). The sum of the points are used to assist the evaluator in making the stream type determination where a minimum of 19 points represents an intermittent stream and a minimum of 30 points represents a perennial stream. Using ArcPad Application Builder, a graphic interface was created mimicking the paper form (Figure 1). For each characteristic a drop down menu allows the user to select “Absent”, “Weak”, “Moderate”, or “Strong” indicating the presence and degree of development of the feature. In some cases the choices are “Yes” and “No” if the indicator is ranked only by whether it is present or not. Each choice is mapped to a numeric value which ranges in ascending or descending order. For example the “Strong” presence of fibrous roots in the stream channel indicates lack of perennial flow and therefore is assigned 0 points. Inversely the “Strong” presence of head cuts is an indicator of perennial flow and receives a value of 3.

Table 1. North Carolina Division of Water Quality, Stream Identification Form. Version 3.1

Date:	**Project**:	**Latitude:**
Evaluator:	**Site:**	**Longitude:**
Total Points: *Stream is at least intermittent if ≥ 19 or perennial if ≥ 30*	**County:**	**Other** *e.g. Quad Name*:

A. Geomorphology (Subtotal =_________)	**Absent**	**Weak**	**Moderate**	**Strong**
1[a]. Continuous bed and bank	0	1	2	3
2. Sinuosity	0	1	2	3
3. In-channel structure: riffle-pool sequence	0	1	2	3
4. Soil texture or stream substrate sorting	0	1	2	3
5. Active/relic floodplain	0	1	2	3
6. Depositional bars or benches	0	1	2	3
7. Braided channel	0	1	2	3
8. Recent alluvial deposits	0	1	2	3
9[a] Natural Levees	0	1	2	3
10. Headcuts	0	1	2	3
11. Grade controls	0	0.5	1	1.5
12. Natural valley and drainageway	0	0.5	1	1.5
13. Second or greater order channel on <u>existing</u> USGS or NRCS map or other documented evidence.	No = 0		Yes = 3	

[a]Man-made ditches are not rated; see discussions in manual

B. Hydrology (Subtotal = _________)				
14. Groundwater flow/discharge	0	1	2	3
15. Water in channel and > 48 hrs since rain, **<u>or</u>** Water in channel -- dry or growing season	0	1	2	3
16. Leaflitter	1.5	1	0.5	0
17. Sediment on plants	0	0.5	1	1.5
18. Organic debris lines or piles (Wrack lines)	0	0.5	1	1.5
19. Hydric soils (redoximorphic features) present?	No = 0		Yes = 1.5	

C. Biology (Subtotal = _________)				
20[b]. Fibrous roots in channel	3	2	1	0
21[b]. Rooted plants in channel	3	2	1	0
22. Crayfish	0	0.5	1	1.5
23. Bivalves	0	1	2	3
24. Fish	0	0.5	1	1.5
25. Amphibians	0	0.5	1	1.5
26. Macrobenthos (note diversity and abundance)	0	0.5	1	1.5
27. Filamentous algae; periphyton	0	0.5	1	1.5
28. Iron oxidizing bacteria/fungus.	0	0.5	1	1.5
29[b]. Wetland plants in streambed	FAC=0.5 FACW=0.75 OBL=1.5 SAV= 2.0 Other = 0			

[b] Items 20 and 21 focus on the presence of upland plants, Item 29 focuses on the presence of aquatic or wetland plants.

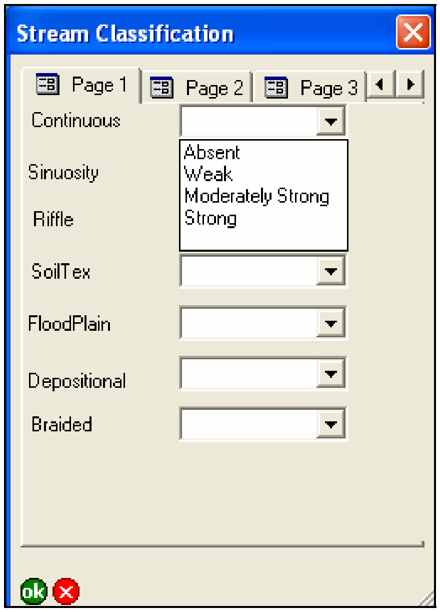

Figure 1. Example of hand held computer touch screen input for field recording of stream identification factors.

Once the user has assigned values to each of the 29 indicators, a Visual Basic script calculates the total points of all indicators and returns the stream origin type to another field. The stylus is then used to input additional information pertaining to the site, such as county name, and a unique identifier for the point labeled "Reach Code". Finally a time and date stamp are written to the shapefile for the purpose of matching origin points to digital pictures using the time the photo was taken. This feature is significant when conducting a multi-day survey involving hundreds of origins. ArcPad 7 includes an extension for writing position information to the digital photo which would have reduced the amount of time spent matching digital photographs to their respective origin, however this option was not utilized for the development of this project. Coordinates for the origin are recorded in NAD 1983 State Plane North Carolina FIPS 3200 (Feet) and point averaging using 120 points. Update frequency was set in the GPS firmware at 2 second intervals. All attributes including the value for each characteristic were stored in a shapefile on a Secure Digital (SD) card.

Upon return from the field, the "Stream_Origin" shapefile is imported into an identical feature class in an ESRI SDE geodatabase. All of the attributes have been enabled with coded value domains enabling the ability to edit attribute properties using the same drop down menu choices, provided that a review of the digital photographs dictated such necessary changes. Using Arc Hydro a unique HyrdoID was assigned to each origin feature and local topographic variables were recorded for that point such as drainage area and average slope using the Arc Hydro tools. Further attributes were stored in the geodatabase such as project name, local environment variables taken from geologic and soil layers, and yearly average rainfall. Statistical software packages such as SAS or R can then be configured to access the Oracle database storing the geographic data to perform multivariate or principal component analysis to determine which environmental variables most influence the determination of intermittent and perennial stream origins.

An additional real time wireless server connection was developed as well. This connection utilizes broadband wireless connectivity and, through an ArcGIS Server, writes attribute updates directly to the Oracle database via the wireless connection. Upon completion of the data input form, a Visual Basic script assembles a URL string. The URL consists of a domain corresponding to an ARCGIS server page as a post request. The URL string includes all the field names from the stream ID form and values assigned to them by the user. Each field name and value pair are separated by the character "$" and the field name is separated from its paired value by the "_" character. For example, a "Weak Head cut" is represented as "$HEADCUT$_1". The script can further be used to initialize the URL through any existing network connection. Upon successful transmission of the post request, the ArcGIS Server page establishes a connection to an ArcSDE feature class. The URL string is parsed to a one dimensional array utilizing the "split" method on the "$" character. Each cell in this array consists of a field name and value separated by the "_" character. The server page then loops through this array and utilizes the split method again on each cell splitting on the "_" character. This yields 2 strings per array cell, a field name and a value for the field. With the existing connection to the feature class, the server page will populate each field in the Oracle database with the corresponding value and repeat the loop until the array is exhausted. Utilizing this method it is possible for field surveyors to update database records without having to physically return to an office location, thus reducing time and effort and improving data collection efficiency. Further configuration would allow instantaneous access to the spatial information via a web server, which would allow the immediate transfer of data to public or private users through a web interface.

DISCUSSION

This stream ID application developed for ArcPad has been tested on numerous mobile computing devices including tablet PCs, ruggedized laptops, and proprietary GPS devices that use Pocket PC or Windows CE. When using GPS devices that do not receive real time position correction through a beacon receiver such as Trimble GEO XM, the Arc Pad extension Trimble GPS Correct, makes it possible for the user to differentially correct the shapefile on a workstation. The digital stream identification form has also been replicated as a proprietary Trimble and Leica data dictionary. Users who cannot accommodate ArcPad in fiscal operating budgets can still benefit from the features of a standardized interface for recording stream attributes. However additional operations are necessary for uploading the GPS data to the Oracle geodatabase which may prove to be more technically challenging than the procedures described here.

The stream identification mobile GIS platform was developed to support the field work for a project that involves locating and mapping headwater streams throughout the state of North Carolina. However, the methods are compatible with other areas where a unified procedure for determining stream origin has not been established. The main goal of the project is to identify local environmental variables that influence channel initiation thresholds of headwater streams in various physiographic settings. Furthermore, methods for interpolating Digital Elevation Models (DEM) are being analyzed to determine which channel initiation criteria and topographic variables best predict the location of intermittent and perennial break points as well as positional accuracy of stream channels modeled using GIS tools. With the aid of the hand held digital stream identification form a tremendous amount of information is obtained for each stream origin in a data format that is compatible with administrative protocols set forth by the State of North Carolina. During preliminary surveys using the system it was discovered that additional attributes needed to be added to the schema such as “Contributing Area” and “Basin Relief”. The use of the Oracle geodatabase as a central repository for project data provided an advantage that changes to the database schema could be made at one location and distributed to users system-wide. Attribute fields mimicked output from Arc Hydro tools that are used to generate values for those attributes.

The ArcPad application will work on any computing device capable of running ArcPad 6.x or higher. It is available for download at http://arcscripts.esri.com/details.asp?dbid=13735. In this study, 150 stream origins have been surveyed using this platform with plans for approximately 400 more utilizing teams of private consultants contracted to assist in the time and cost effective collection of field data for model development. The mobile GIS discussed here demonstrates how significant resources, predominantly time, can be saved by forward engineering many time intensive tasks. These include paper record keeping, and delivery of results into a portable client-server architecture that accomplishes all facets of a stream survey, from collection of field data, to classification and presentation of survey data in an understandable format to decision makers.

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