Chapter One – The Need for Data

Today's environmental agencies require more data than ever before. A new focus on collaborative environmental management has resulted in an unprecedented need for information to address environmental issues effectively. A key component of this new focus, the 1972 Clean Water Act (CWA), U.S.C. Section 1313, forever changed the way in which the United States looked at water quality. Section 303 of the CWA mandated the Total Maximum Daily Load (TMDL) process, which requires state, territorial, and tribal governments to report all waters listed as "impaired" to the Environmental Protection Agency (EPA) every four years. Impaired waters are those that do not meet state and/or Federal water quality standards for any of several indicators. The TMDL is a document that describes:

- The impaired segment – the portion of the waterbody that does not meet applicable water quality standards,
- The cause of the impairment – the factor(s) that result in the impaired designation (e.g. nutrient enrichment),
- The source(s) of pollution – point discharges and nonpoint sources that contribute to the pollutant loading causing the impairment,
- An allocation of the pollutant to the sources – a plan that would bring the water into compliance with standards concerning the specific pollutant by limiting the amount of pollution originating from each of the sources
- An adequate margin of safety – an allowance for any lack of knowledge concerning the relationship between effluent limitations and water quality (Overview, 2001).

Additionally, in Virginia, the Water Quality Monitoring Information and Restoration Act (WQMIRA) requires the development of TMDL implementation plans detailing the steps necessary to achieve the water quality standards in impaired waters by reducing the pollutant load from the various sources, including point source reductions and nonpoint source best management practices (BMPs). Additionally, a "reasonable assurance" that these plans can and will obtain the desired results is called for by the WQMIRA legislation.

Since the inception of the CWA, pollution originating solely from point sources, such as water treatment plants and industrial facilities has been reduced to 10% of the total pollutant load to American waters. The remaining 90% of the total is evenly split between nonpoint sources only (43%) and a combination of point and nonpoint sources (47%) (TMDL Program, 2001). In order to implement the requirements of the TMDL legislation, these nonpoint sources must be accurately measured and accounted for in the process. Lack of adequate data concerning nonpoint sources often forces regulatory agencies to make assumptions and decisions that unfairly impact certain stakeholders without addressing the true source of the problem. Expensive controls may be placed on the easily identifiable sources, which actually contribute very little to the total pollution load. A TMDL plan based on inadequate data could become a very expensive and inequitable waste of time and resources.

It is evident that the important task of properly accounting for nonpoint source pollution in the TMDL process requires large amounts of data. Extensive data on pollution levels and sources must be gathered and analyzed in order to determine the most effective loading allocation for a stream or river. In fact, the monitoring requirements demanded by the TMDL process can quickly overwhelm an environmental regulatory agency's manpower and resources. In their joint November, 2000 report to the governor, the Virginia Department of Environmental Quality (DEQ), the Virginia Department of Conservation and Recreation (DCR), and the Virginia Department of Mines, Minerals, and Energy (DMME) estimate the total cost of a ten-year TMDL implementation plan at just over $59 million, with the addition of 15 positions at DEQ and 21 positions at DCR. At the currently forecasted level of funding, this figure outstrips the available budget by more than $40 million (Treacy 2000).

As a result of a new focus on environmental management demonstrated by the TMDL process, agencies across the country face budget and personnel constraints similar to those described above. Over 21,000 impaired river segments, lakes and estuaries have been identified in the United States. Each of these impaired waterbodies requires a highly detailed TMDL document. Environmental agencies must collect data on possible point and nonpoint source loadings for every one of them. For many years, there has been a debate concerning the ability of the nation's environmental agencies to meet this challenge.

A recently released report by the National Academy of Science (NAS) concluded, "there are ways to accommodate this uncertainty [in the science behind the TMDL process] while still moving forward in achieving the nation's water quality goals" (Rogers and Hazlett, 2001). However, they also suggested many improvements that would require more extensive and detailed data collection. These recommendations are:

- To encompass all stressors that determine the condition of a waterbody,
- To make substantial efforts to reduce the unknown,
- To assess the achievement of water quality standards on a regular basis, and
- To use biological criteria in conjunction with physical and chemical criteria.

As a result of the NAS study, EPA has delayed the release of its final rules for the TMDL process. One can only assume that some, or many, of these suggestions will be included in the new revisions. If these suggestions are incorporated into the new rules governing TMDL development, environmental regulatory agencies across the nation will be under even greater pressure to collect greater quantities of useful and detailed information.

The TMDL legislation stands as only one example of the increasing pressure for environmental agencies to monitor more areas with a greater level of detail. Similar arguments could be made for any data intensive process. In almost every professional field, advances in knowledge and technology, coupled with a shift in the overall focus of data collection and modeling towards a more comprehensive view, has resulted in an unprecedented need for data.

The high costs associated with current levels of data collection and the potential for an even greater demand for data in the future compounds the necessity to find more effective methods of collecting and processing information. Consequently, many agencies have begun to expand their "collection nets" in new and creative ways in an effort to meet the demand for information.

Increasingly, agencies are utilizing data available from volunteer environmental groups to supplement their own monitoring efforts. This research is intended to assist these agencies and volunteer organizations by providing a new tool that can aid in expanding these nets. The ideas and methods presented here are meant to increase the ability of both agency personnel and volunteer groups to efficiently produce useful and reliable data.

This research focused on the integration of a Personal Digital Assistant (PDA), a Global Positioning System (GPS), a digital camera and a Geographic Information System (GIS) with existing visual stream assessment methods used by volunteer groups. Chapter 2 introduces volunteer stream monitoring and its advantages and disadvantages. Chapter 3 compares traditional data collection tools to the new tools mentioned above. Chapter 4 describes the stream assessment method, the software and the hardware used during this research. Chapter 5 provides details on the development of the PDA-based data collection method and two field applications. An evaluation of the method and the lessons learned from the field tests are given in Chapter 6. Finally, Examples of the paper forms used to develop the PDA-based method, along with descriptions of the conditions recorded by this method, are given in Appendix A. Finally, Appendix B illustrates examples of the integration of these technologies into applications outside of environmental management.

Chapter Two – Expanding the Data Collection Net

In order to meet this growing demand for data, many agencies have established some form of a volunteer monitoring network. The less technical, more labor intensive aspects of watershed management, such as sample collection and basic biological surveys, can be delegated to local watershed groups with an interest in the health of the watershed. After an initial training period, many volunteer organizations can schedule and perform monitoring activities with little or no input or supervision from the agency. An occasional meeting to answer questions and exchange information is often the extent of agency input into the volunteer monitoring process. Minimal input of time and funding makes manpower available through a volunteer monitoring network essentially free labor.

What is Volunteer Stream Monitoring?

Volunteer stream monitoring is a simple concept that uses the time, energy and dedication of local volunteer groups, interested citizens and/or students to monitor the health and conditions of local waterbodies. Volunteers are responsible for gathering, analyzing and submitting data on a wide variety of conditions, including biological health and diversity, chemical properties of the water, and visual assessments of potential problems along the stream corridor. Local environmental agencies then use this data to supplement their own data collection efforts.

What are the advantages for local agencies?

Volunteer organizations can often observe sites that the local agency is unable to monitor regularly. Information gathered by the organizations can be used to screen these sites for any potential environmental problems without the need to dedicate significant agency resources. Also, data gathered through volunteer monitoring efforts can be used to establish trends in waters that are not extensively monitored by the local agency. These trends can demonstrate the natural fluctuation of the waterbody and lead to a more effective management plan for the corresponding watershed. By taking advantage of the time and enthusiasm of volunteer monitoring groups, agency personnel can focus their knowledge and expertise on problems that have been identified, while the volunteer organizations keep an eye out for new ones.

In a larger context, a volunteer monitoring network builds community capacity by adding to the knowledge of the entire community and fostering new relationships both within the community and with individuals, groups, and organizations outside of the community. The network allows an agency to foster cooperative relationships within the watershed and effectively develop and communicate a management plan that residents will support.

What are the advantages for private citizens?

Volunteer stream monitoring provides local citizens with a unique opportunity to learn about local water quality issues. The volunteers also gain new respect for the intricate relationships found in their local environment. By sampling and analyzing water, volunteer organizations can help local agencies locate and address water quality problems.

More basic types of volunteer monitoring, such as visual watershed surveys and stream corridor assessments, allow citizens to develop an inventory of streamside conditions and land uses in the watershed. Typically, these methods document information on any conditions that could potentially affect the water quality of nearby streams. This information can reveal areas that are important to the health of the watershed or may cause water-related problems in the future.

Volunteers can also evaluate the health of stream habitats and aquatic communities to prioritize conservation and/or restoration efforts. By developing a strategy and approaching conservation and restoration with a definite plan of action, concerned residents can more effectively work to improve their local environment. Additionally, through processes like these, volunteers acquire technical knowledge and an understanding of the "inner workings" of their environmental agency through the training process, as well as developing a long-term relationship with the agency.

What are the disadvantages of Volunteer Stream Monitoring?

Volunteer stream monitoring has the potential to follow available resources. Those communities with the time, money and energy to engage in volunteer monitoring typically have more effective programs. The presence of relevant and detailed monitoring data from an effective volunteer group has a tendency to draw the attention of local agencies to these areas. Those communities with more severe problems, but less effective volunteer monitoring programs could suffer from this diversion of agency commitment. Volunteer groups and environmental agencies alike should recognize and account for this "resource gap" when deciding to focus only on certain communities

On the other hand, agencies may feel that communities with effective volunteer monitoring do not require the level of detail and attention of other areas. They may decide to concentrate their resources in other areas and trust the information provided by the volunteer groups of the community. However, few volunteer groups have the depth of technical knowledge and expertise of an environmental agency, which may allow seemingly unimportant factors to be overlooked. While volunteer data can be a valuable asset to local environmental agencies, it can never replace the knowledge and experience of agency personnel.

Chapter Three – The Tools of Data Collection

Currently, many environmental agencies throughout the United States rely primarily on limited numbers of data collection stations. Most monitoring and gauging stations are established at points in a given watershed based on some regional criteria. The placement of these stations may or may not be suited to the unique characteristics of each particular watershed. These stations can be remotely monitored using an automated data collection system to record water quality criteria. However, available time and resources limit the level of detail provided by this method. Also, the systems are designed to monitor only specific aspects of the overall health of the aquatic system. Although automated data collection can provide a good general overview of the health of the watershed, it cannot provide the entire picture. In order to supplement the automated systems, many agencies conduct field data collection (see Figure 3.1).

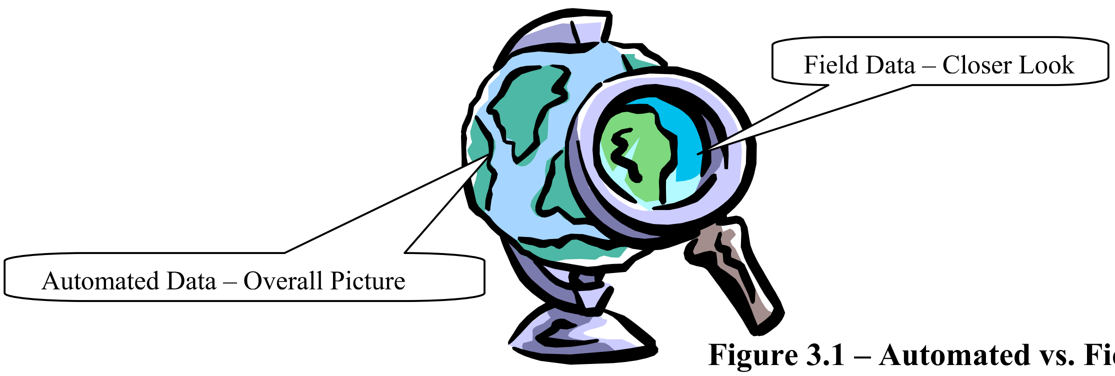

Figure 3.1 – Automated vs. Field data

Traditionally, agency personnel in the field complete a standard evaluation form, including information on the site, sketches of the site, and an estimate of the location on a copy of a topographic map. The forms are then returned to the office and entered into a computer database for storage and analysis, or tucked neatly away in a filing cabinet. This method, while popularly used, presents a few unique problems both in the field and in the office.

In the Field

Several aspects of traditional paper-based data collection methods make them less than ideal in the field. Handwritten, unstructured descriptions of important aspects of the site will always contain the bias of the evaluator. While providing a list of options limits this possibility, a determined surveyor will always create a new category, which can cause problems when the recorded data does not fit any of the predefined data input categories. Also, as a record of the location of a site, a hand-drawn dot on a copy of a map is not always accurate. It can be quite easy to erroneously mark your position or move beyond the boundaries of a hard copy map.

Surveyors often overlook sections of the form under unfavorable circumstances. The intense heat of a July afternoon or the bitter cold of a January morning can inhibit the attention given to accurately and fully completing a paper-based survey. Finally, under almost any circumstance, handwritten evaluation forms have a natural tendency to either completely disappear or attract stains and smudges in the most inconvenient places. Illegible or missing survey sheets can disrupt data input or even require another trip to the site to perform an additional survey.

In the Office

The problems associated with paper-based survey methods extend into the office as well. Transcribing data from paper surveys into a computer database is a tedious and boring task prone to errors. Individual handwriting can also be misinterpreted while being transferred into the computer database. Such mistakes in the data input process are hard to catch without an adequate quality control system. However, dedicating time, personnel and resources to quality control hampers the progress of the survey in the field. Further, this form of data entry requires trained individuals to be taken from the field, or the recruitment of additional employees or volunteers to perform the data input. Finally, sharing information stored as paper copies of maps and handwritten survey forms with other agencies and organizations is sometimes difficult. The cost and time associated with preparing, packaging and mailing the information can be considerable when compared to alternative forms of data distribution, such as email or websites.

The New Tools

Four recently developed technologies have the potential of revolutionizing the data collection process for many applications. The advantages of these technologies can greatly enhance data collection by allowing users to gather data more efficiently. They also provide accurate positional information, as well as detailed and descriptive images of the data point, all of which can be quickly and easily inserted and linked in a database.

The first of these, Personal Digital Assistants (PDAs), also known as handheld computers, palmtops or pen computers, put the functionality and power of a desktop computer in the palm of your hand. Secondly, digital cameras allow for the collection and rapid processing of images from the field. The Global Positioning System (GPS) has already gained a great deal of popularity in many applications. GPS units allow users to accurately record the location of a data point almost anywhere in the world. Finally, geographic information systems (GIS) allow users to link all of this information, along with information from many other sources, in a spatially referenced database. The last two technological developments are sometimes referred to as *geospatial information technologies*.

<u>*Personal Digital Assistants*</u>

PDAs have been adapted to serve a wide variety of purposes in a broad range of fields. With rapidly expanding memory capacity and an extensive base of software developers, the PDA revolution is in full swing. As a result of the development of the "keyboardless" handwriting recognition systems in 1995, the handheld computing market exploded. Handheld systems quickly adapted to meet the varied needs of consumers. The development of simple "synchronization" techniques to transfer data between a desktop system and a handheld has further expanded the potential of these devices. With this power, virtually all of the data traditionally entered in the office can be done as data are collected in the field.

Upon returning to the office, a simple synchronization transfers the field data directly to the computer. There are no messy paper forms to shuffle through and input into the database. The information can also be quickly exported to other programs for advanced analysis. Developers have continued to increase the functionality of PDA devices by providing the ability to attach peripherals, such as cell phones, printers, additional memory modules, modems, digital cameras and GPS units. An incredible range of peripherals and software that utilize the PDAs adaptability is available through several third party developers that have taken advantage of this aspect of handheld computing (PCTechGuide 2001).

<u>*Digital Cameras*</u>

Surprisingly, digital photography is not a very recent technological development. Early versions of the technology were used on military spy satellites in connection to the beginning of the Cold War. As the Cold War came to a close in the late 1980s and early 90s, professional graphics studios and photographers began adapting the technology into desktop publishing applications. It eliminates the time required to process film and print hard copy pictures. Instead of relying on film, digital cameras work by storing images in much the same way a desktop computer stores a file.

Many digital cameras allow users to review pictures immediately after they are taken. Using this function to check images in the field ensures that the photographs capture the desired attributes of the site. Also, for any agency or organization involved in surveys that require photographic documentation, digital cameras eliminate the cost and delay associated with processing, scanning, cataloging and storing photographs taken with traditional cameras. The images can be transferred directly to the computer and inserted into any report or presentation as an interesting and descriptive illustration of the survey data (HC+T Column 2001).

Global Positioning Systems

GPS units have become quite popular in recent years. Their applications range from precision boundary surveys and fault line measurements for earthquake prediction to locating a favorite fishing hole or navigating from the mountains to the vacation resort on the beach. These systems rely on a network of global satellites to accurately determine their position at any point on the earth. With a clear view of at least four satellites, most GPS units can locate a position with an accuracy of ± 10 meters. The positional information from a GPS unit is universally understandable and easily transferred among agencies, unlike the roughly estimated point on a map described earlier.

GPS technology evolved into its present form in a mere three decades. The original GPS units were developed for military applications in the 1970s. As the technology became more advanced and the vast potential for civilian uses became apparent, GPS units began to be sold on the open market. It is now possible to purchase a basic, but reliable, GPS unit (± 10m) for around $150 at many sporting goods retailers. Most GPS units work with the same general interface and are essentially interchangeable in many applications. The increase in cost of a GPS unit is most often associated with the accuracy the unit can achieve ("GARMIN" 2001).

Geographic Information Systems

Simply put, GIS "combines all of the capabilities of display-only, thematic and street-based mapping systems with the ability to analyze geographic locations and the information linked to those locations" (ESRI 1999). It can be thought of as a custom-made map that shows only the information you request. For example, a map showing local streams, roads and existing underground storage tanks can be created with a few clicks of the mouse. Imagine trying to compile this data into a map without a GIS. Many painstaking hours of survey work and hand or CAD drafting would be necessary to produce a map with only those datasets.

Any datasets available in the database can be displayed in any combination. Layering data sets in this way gives a GIS a unique advantage over its paper counterparts. By layering the dataset of existing underground storage tanks over the stream network dataset, a user can quickly determine which streams leaking tanks may impact. The complicated and time-consuming paper overlay process is replaced with a few minutes of GIS manipulation.

Also, paper maps only show you the location of various features and their names, if you're lucky. A GIS can display the locations of features and any aspect of that feature contained in the database. In order to prioritize monitoring efforts, the underground storage tanks could be classified and labeled based on storage capacity or age.

Finally, updating the database is extremely simple. Through an edit command, any new underground tanks can be quickly added to the dataset and ones that are taken out can be removed. Using paper maps, each existing copy must be accounted for and either replaced or altered to match the new conditions.

Used separately, or in combination, these technologies provide a distinct advantage over more traditional data collection methods. Data collection using a PDA and digital camera is consistently described as efficient, reliable and detailed. GPS and GIS technology make the visualization of this data easier than it has ever been. It isn't hard to see that adapting traditional field data collection methods to take advantage of these new technologies can provide immense benefits to environmental agencies and organizations.

However, many of these technologies have relatively high start-up costs and training requirements that may inhibit their use in some instances. Also, given the rapid advancements of technology, the state-of-the-art system purchased today may become obsolete within a short period of time. These factors should be carefully considered in any decision to make an investment in these types of systems.

Table 3. 1 – Advantages and Disadvantages of the New Data Collection Tools

Advantages	Disadvantages
Ease of use in the field	High start-up costs
Improved consistency of data	Additional training necessary
More efficient entry of data in the office	Technological obsolescence
Ability to collect and display more detailed information	

Chapter Four – Combining the Tools and the Technology

Similar to the examples presented earlier, agencies and organizations involved in environmental management would benefit from a simple, standardized protocol that utilizes the benefits available through GPS, PDA and digital imaging technology. Such a protocol could help these groups meet the demand for data brought about by the TMDL legislation and a general shift in the focus of environmental management towards a more holistic approach. This would provide a common format for gathering and displaying information on water quality, water characteristics, and land-related data for use in planning, implementation and monitoring. Such a standardized protocol would also permit interested environmental groups to supplement agency monitoring efforts in order to provide a more complete picture of their watershed.

In Virginia, many environmental groups have expressed interest in assisting the state environmental agencies with water quality monitoring efforts. Currently, each group must develop an individual protocol with the assistance of agency personnel. A standard, easy-to-use protocol would eliminate this time consuming process and expand this useful data resource to help meet the demanding information requirements of environmental management. However, the technology is new to the environmental field and may not be suited for advanced applications, such as streamflow measurement or benthic macroinvertbrate surveys, at this time. The functionality and durability of the equipment may not be adequate for these more demanding uses. Further research is needed to fully develop the potential of these devices in the profession of environmental management.

The method presented here is only the first step in this development process and as such, has been purposefully kept as simple as possible. The emphasis of this research is the user interface with the new technologies, not the existing evaluation methods. Users should not be hampered by a complex data collection system. With this in mind, simple data collection forms that are popular with several volunteer organizations in the region were adapted to the new application. The survey method was selected based on the following criteria:

- Simple to use and understand – the selected survey method should be one that has been proven as an effective and understandable instrument.
- Minimal training and assessment time – the emphasis should be on the functionality and usefulness of the technology not the survey instrument.

- Useful data – the survey should provide data that interested environmental groups and agencies could use in their management efforts.

Database Design

The GPS/PDA database is based on existing work on volunteer stream assessment by a researcher at the Virginia Water Resources Research Center (VWRRC) at Virginia Tech (de Leon 2001). The selected database is a unique combination of two forms of visual stream assessment developed for the Stroubles Creek Corridor Assessment. This combined survey method had the distinct advantage of access to experienced users. The creativity of this method and the availability of users who were familiar with the method led to its selection.

The method is relatively simple and designed for a rapid assessment of the visual condition of a stream corridor. Therefore, it would be easy to build into a database and would provide information that is useful to many agencies and organizations. In particular, the VWRRC requested that the stream survey be performed as part of the development of TMDL documents for six impaired stream segments. Details on the surveys are provided in Chapter 6.

The survey method is based on two variations of visual stream assessment: the Stream Corridor Assessment (SCA) method supported by the Maryland Department of Natural Resources and sections of the methods presented in EPA's Volunteer Stream Monitoring: A Methods Manual. A copy of the paper survey sheets is provided in Appendix A.

Stream Corridor Assessment

Environmental groups interested in providing useful supplemental data about their local streams and rivers to state and local environmental agencies developed the SCA method for use in their water monitoring efforts. To date, the survey has been performed on over 700 miles of streams by the Adopt-A-Stream program in Maryland. The method catalogs nine distinct "problem conditions" that can be found along a stream corridor. Along with specific data concerning each problem, the method scores each occurrence according to its severity, correctability and access, so that each problem can be ranked based on how bad it is, how easy it is to correct and how difficult it is to get equipment to the site. This ranking provides a group or agency with a means of prioritizing the problems along the stream corridor and allows a more efficient allocation of resources to address the problems. Descriptions of the problem conditions and the specific data collected on each are given below (Yettman 2000).

Table 4. 1 – Stream Corridor Assessment (SCA) Problem Conditions

Problem Condition	Description	Recorded Data
Channel Alteration	Widening, straightening, artificial channels	Type, size, presence of sedimentation/vegetation
Construction Site	In/near stream construction	Type, erosion control, location
Erosion Site	Occurrences\ of stream bank erosion	Location, extent, land uses, potential damage
Exposed Pipe	Pipe that could be damaged during high flow events	Degree of exposure, type, size, purpose, discharge
Fish Barrier	Blockage of upstream movement of fish	Degree, type
Inadequate Buffer	Inadequate wooded buffer shading the stream	Location, % unshaded stream, length/width of existing buffers, land uses
Pipe Outfall	Pipes or ditches discharging to the stream	Type, size, location, discharge
Trash Dumping	Trash deposited in the stream or along the banks	Type, amount, distribution, volunteer clean-up potential, land ownership
Unusual condition	Any notable situation that does not fit the other categories	Detailed description of the condition

EPA's Volunteer Stream Monitoring Methods Manual

The Visual Assessment and Stream Habitat Walk protocols adopted from EPA's manual on volunteer monitoring are intended to provide a more in-depth look at general stream conditions, such as bottom type, riparian vegetation, and habitat. The Visual Assessment protocol recommended by EPA is used to document the overall visual appearance of the stream. The sections that have been adapted from it catalog the following attributes of the waterbody:

- Weather (in the past 24 hours and currently)
- Locations of specific land uses (streamside, within ¼ mile, within watershed)

The Stream Habitat Walk protocol is used to document the availability and quality of aquatic habitat in the stream. Sections taken from it record information on these parameters:

Table 4. 2 – Stream Habitat Walk Parameters

Stream habitat types (pool, riffle, run)
Make up of the stream bottom (silt, gravel, etc.)
Embeddedness of the stream bottom
Large woody debris in the stream channel
Organic material in the stream (leaves, twigs, etc.)
Appearance and odor of the water
Approximate width(s) and depth(s) of the stream
Slope and condition of the stream banks (gradual/steep, percent modification)
Land cover along the stream (trees, pavement, lawns, etc.)
Presence of wildlife, fish, aquatic plants and algae

EPA recommends performing a stream survey on consecutive 100-yard sections of the stream. In rural areas, this frequency of surveying provides very little additional data. Streams located in rural areas do not undergo significant changes over such distances. For this application, the method is adapted to allow for a more rapid assessment of the stream by conducting a survey only when conditions warrant a new survey. For example, a team will always begin a streamwalk by conducting a survey on the first 100 feet of the stream. As the team progresses along the stream, members note the condition of the stream and surrounding area. When a significant change is noticed, for instance, the streambed changes from rocky to silty, or the stream flows out of a forest into an open field, a new survey is taken. The team progresses along the stream in this manner, beginning a new survey only when conditions change noticeably (USEPA 1997).

Software Selection

The software selected for the protocol was chosen based on its ease of use, customizability, and affordability. The program had to be able to incorporate the evaluation forms in a useable manner and also interact with a GPS unit without a significant investment of time or resources. Extensive online research resulted in four options:

Table 4. 3 – PDA-based Data Collection Applications That Were Considered

Software Title	Reason for Dismissal
ThinkDB www.thinkingbytes.com	Incompatible with available GPS unit
Stick-e Suite www.cs.ukc.ac.uk/projects/mobicomp/Fieldwork/index.html	No desktop database design/maintenance software
GeoGIS www.geoinsight.com	Expensive, too complicated for basic visual assessments

The chosen software, a freeware package known as CyberTracker™, was found to meet all of these requirements (Figure 4.1). CyberTracker is a data collection tool developed in South Africa. It was originally used to tap the unique knowledge and expertise of illiterate South African Bushmen to monitor the movements and behavior of wildlife. The software developers describe it as:

> "The most efficient way to gather large quantities of data for field observations, even by illiterate users, at a level of detail not possible before."

Usage of the program has expanded worldwide. Wildlife agencies in India use it to track endangered tigers. Wilderness schools in the America's have adapted it to track native wildlife and describe the program as a very effective educational tool (CyberTracker, 2001).

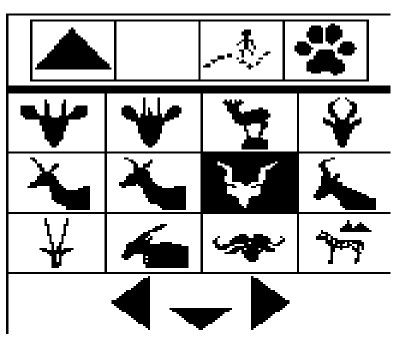

Figure 4.1 - CyberTracker

The program is incredibly flexible. A user can design and maintain a complete database from scratch and develop customized PDA screen interfaces and sequences for use during data collection. The PDA interface can be made to suit any level of understanding. The entire interface can be designed as a totally icon-driven process if so desired, complete with customized icons. Data can then be collected using a PDA and viewed either on the handheld or downloaded to the CyberTracker desktop application for viewing. The program also allows users to query the data and export information for more advanced analysis.

In order to simplify the data collection process and make the database as user friendly as possible, many questions are presented as a list of choices, instead of prompting the user for personal descriptions. If a more detailed description is warranted, the database design does allow it. Help files were also developed on the PDA using the Memo Pad function. Users are able to momentarily leave the CyberTracker program to clarify a selection and return to the same point in the process.

Hardware Selection

Hardware selection for this application was and should always be driven by three criteria: affordability, flexibility, and ease of use. Using these options, various types of PDAs and GPS units were evaluated before a final selection was made. The selected components are described in detail below, followed by a general overview of possible alternatives.

The PDA selected for this research project was the HandSpring Visor Prism. It features a color display, 8 MB of internal memory and the patented Springboard port (Figure 4.2). This port allows for the integration of a wide variety of modules that automatically begin functioning within the PDA interface. HandSpring devices range in price from about $140 for a basic black and white Edge to about $400 for a color Prism. As the research progressed, the need for extended battery life became apparent. A battery backup device manufactured by Tech Center Labs (www.talestuff.com) was purchased online for $40 and provides virtually limitless battery life.

Figure 4.2 – HandSpring Visor Prism

The GPS unit selected for the project was the Geodiscovery Geode (Figure 4.3). The Geode is a SpringBoard compatible module and as such, forms one integrated unit with the HandSpring. This eliminates the cumbersome bundle of cables that is necessary to connect many standalone GPS units to handheld devices. The Geode features advanced satellite acquisition technology that permits it to maintain a lock on a satellite, even in dense tree cover. The unit is capable of 3-meter accuracy with access to a Wide Area Augmentation System (WAAS) satellite. Geode units are priced at $290 and available through a variety of online retailers.

Figure 4.3 –
Geodiscovery Geode

The Olympus Camedia C-2100 digital camera was used to collect images of the problem conditions recorded during the survey (Figure 4.4). The camera features an Optical Image Stabilization System, which compensates for the unsteady hands of the operator. It can record and store up to 128 images at 1600x1200 resolution. An electronic viewfinder allows users to review images in the field and adjust factors if necessary, while a fast 1.2-second shot speed ensures the photographer will be able to work efficiently. The C-2100 is available at several retail locations for around $700.

Figure 4.4 – Olympus
Camedia C-2100

Alternative equipment

The equipment described above is by no means an extensive list of equipment suited to stream assessment applications. The only requirements for the current database are a handheld computer with the Palm operating system and a GPS unit capable of communicating with the software through the NMEA standard protocol. Compatible handhelds are available from both the HandSpring Company and the Palm Corporation starting at $130 and ranging up to $500. A wide variety of GPS units are available from several vendors throughout the United States and around the world. Models that have been popular in handheld computing applications include the Magellan Companion, the Handy GPS, the Garmin GPS12 models and the Garmin eTrex models. A basic GPS unit will cost just over $100 while more advanced models can approach $1,000. Virtually any camera can be used to record images of the problem conditions. If funding is available, digital cameras are recommended due to the ease of image management and the transfer processes. A simple disposable camera can be purchased for around $12 while digital cameras range from $150 to $1,000.

In addition to the technology, which is illustrated in Figure 4.5, basic equipment was necessary to measure the distances and heights called for in many of the problem condition surveys. To meet this requirement, a 300-foot nylon measuring tape and a yardstick were carried as standard survey equipment. Other basic equipment included sunscreen, bug spray, boots, long pants and plenty of water.

Figure 4.5 - PDA/GPS survey setup

Table 4.4 – Price Range for PDA/GPS Field Survey Equipment

	Price Range	Distinguishing Features
Handheld Computers	-	-
HandSpring	$130 - $500	SpringBoard accessories
Palm	$130-$500	Most popular devices
GPS Units	-	-
Geodiscovery Geode	$290	3-m WAAS accuracy
Magellan Companion	$150	Recognized name in GPS technology
Handy GPS	$150	Functionality with a wide range of programs
Garmin GPS units	$100 - $1,000	Functions separately from the PDA
Digital Camera	$150 - $1,000	Direct transfer of images to computer
Total System	$380 - $7,000	-

Chapter Five – Beyond the Desk: The Field Tests

Once the hardware and software were purchased, the database was developed and the system was taken into the field. The design and development of the initial database was completed over a two-week period as I was learning the software. Adjustments were made throughout the study as I became more familiar with its functionality and incorporated the comments received from people using the method.

Database design is accomplished primarily through two functions of the CyberTracker program. Basic data entry and organization is completed using the Data Manager function. Information is entered in a question-answer format. As shown in Figure 5.1, each broad problem condition is input as a "Category," each specific question related to that condition is input as a "Group," with each possible answer as an "Item" in that folder. This setup can be many levels deep, according to the level of detail needed in the survey. The "Structure" category sets up access to the other categories, as well as other functions like team and site selection.

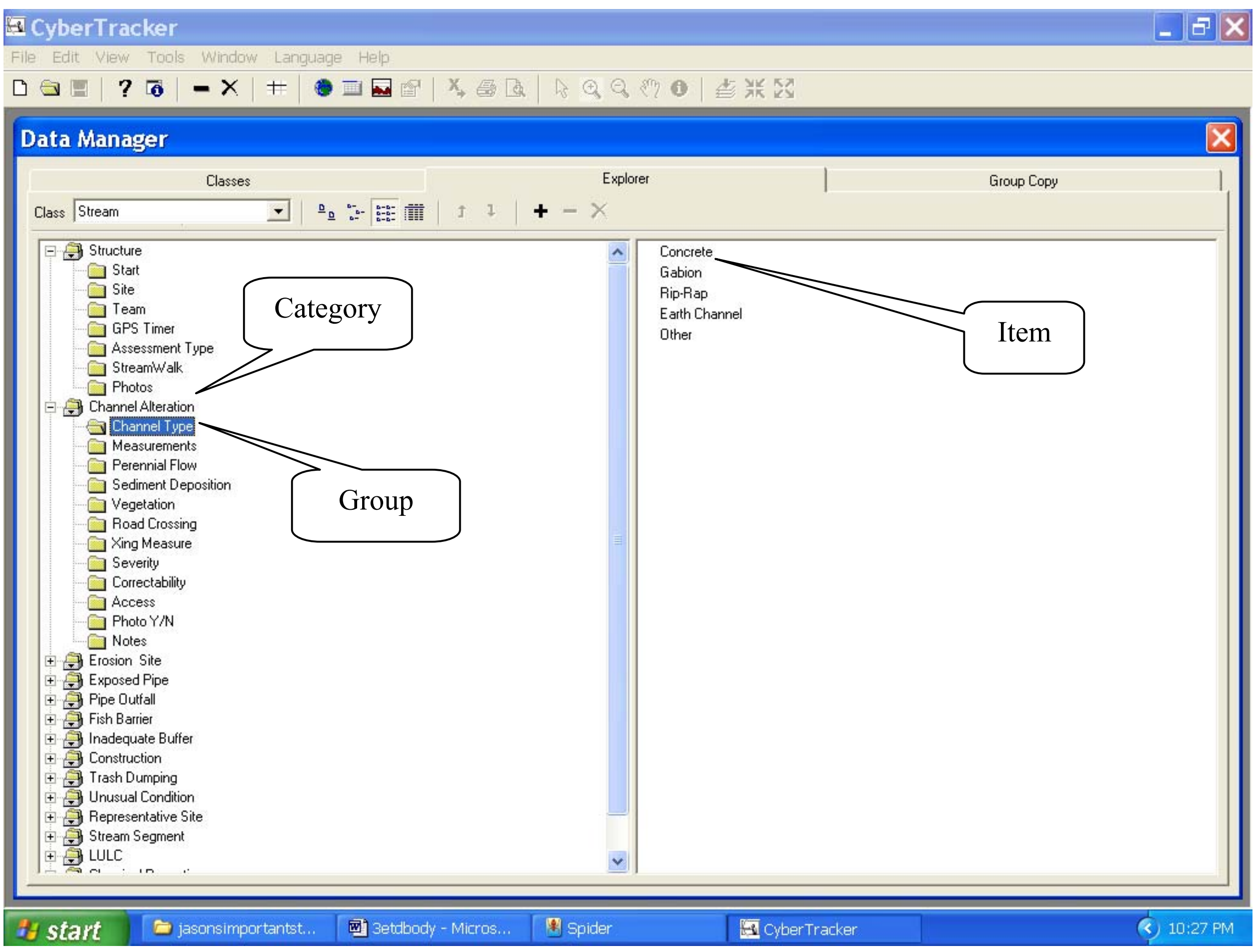

Figure 5.1 – CyberTracker Data Manager

After inputting all questions and answers, the Screen Writer function of CyberTracker was used to build the PDA/GPS method interface and link the questions in a logical sequence. Twelve different types of screens can be built in the Screen Writer, depending upon the type of data it is designed to record. Each screen is named and linked to its corresponding category, group and/or item using the Screen Editor dialog. Screens are linked into a sequence by specifying the next screen, or linking each item to a separate screen. For instance, on the Channel Type screen shown in Figure 5.2, each answer for the screen is linked to a unique screen in the database. After designing and linking all screens, the software has a debug function that permits an easy way to work out any problems with the PDA program before taking it into the field.

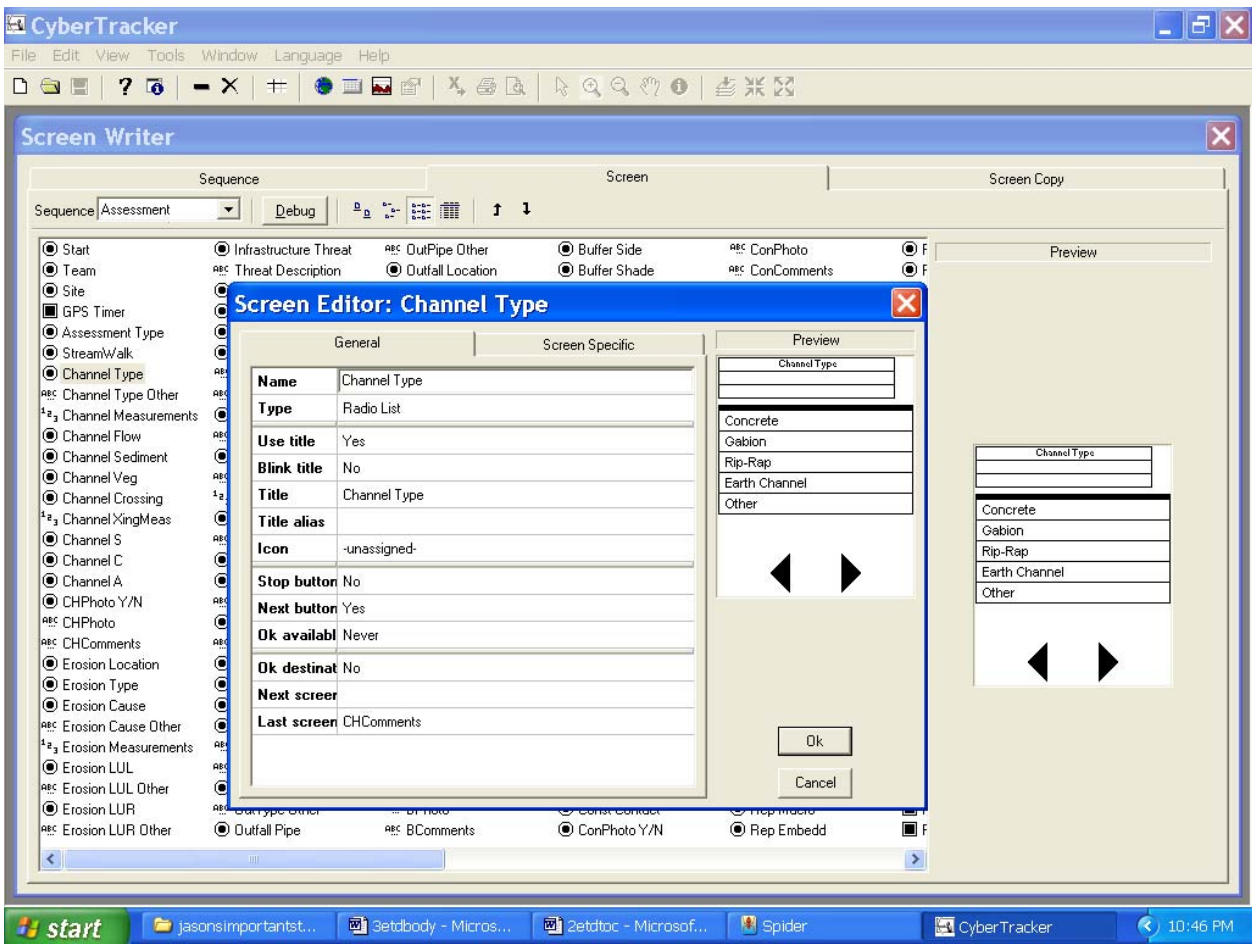

Figure 5.2 – CyberTracker Screen Writer

After designing and debugging the database, each field test was performed following the same basic steps:

- Load StreamWalk from CyberTracker desktop to PDA (See Figure 5.3).
  Using the "Synchronize" function of the CyberTracker program, the database is set up to install automatically with the next Hotsync operation. This process installs both the CyberTracker handheld program and the customized database.

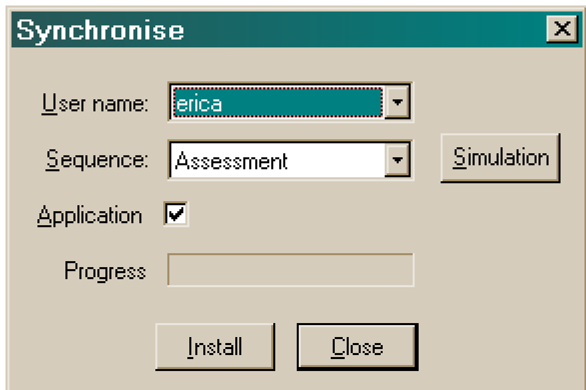

Figure 5.3 – Installing CyberTracker on a PDA

- Perform the StreamWalk (See Figure 5.4)
  Once in the field, the PDA was used to collect information on the problem conditions and stream corridor conditions described earlier. The CyberTracker interface proceeds step-by-step through the questions pertaining to each condition. Once all questions have been answered, unit automatically records a GPS position and returns to the main screen.

Figure 5.4 - Surveyors collecting data on an exposed

- Hotsync data to CyberTracker desktop (See Figure 5.5)

  Upon returning to the office after a streamwalk, data were downloaded to the desktop through a Hotsync operation. The CyberTracker software recognized the new data and prompted the user to update the database.

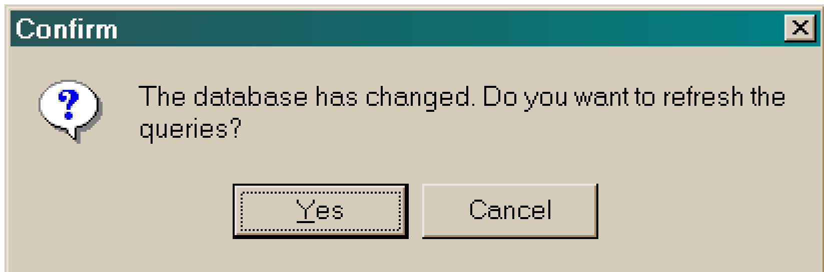

Figure 5.5 – Refreshing queries in CyberTracker

- Query and export desired data to spreadsheet applications (See Figures 5.6a and b)

  The query function of CyberTracker produced data tables containing information on the problem conditions found at each site for export to Excel, or other programs, for advanced analysis.

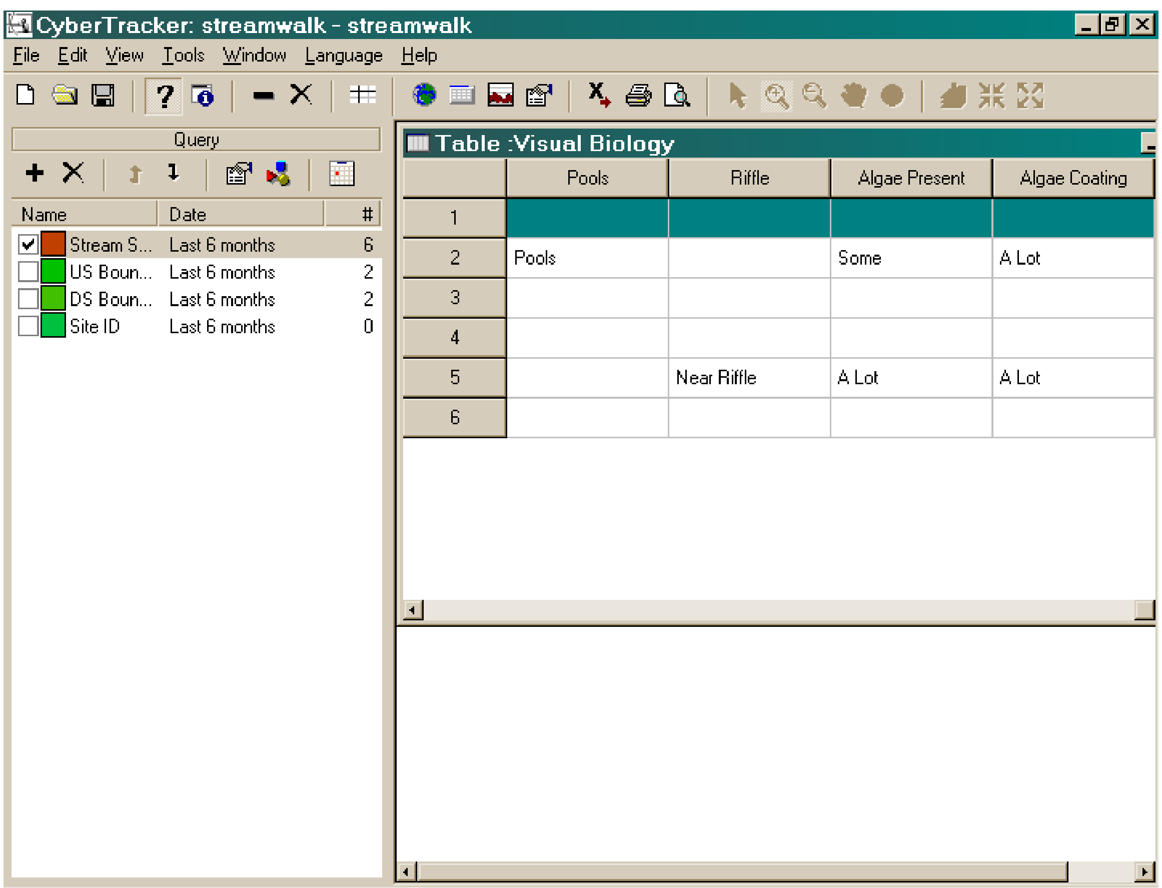

Figure 5.6a – Querying data in CyberTracker

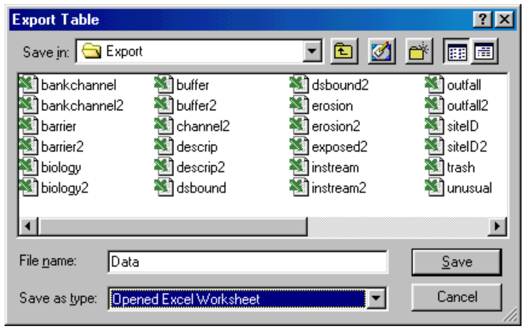

Figure 5.6b - Exporting from CyberTracker

- Import data into a GIS database (See Figure 5.7)

  From Excel, the data were saved as a text file and imported into ArcView GIS as a table. An event theme was created from the table and projected to match existing data sets in the database using the Add Event Theme function of ArcView.

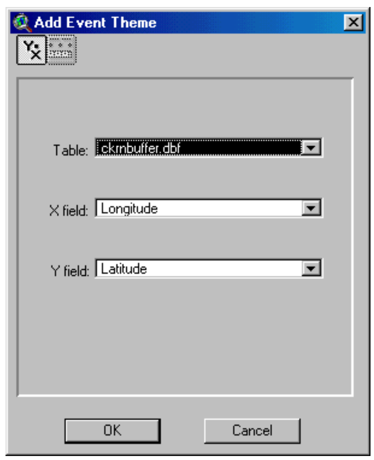

Figure 5.7 - ArcView's Add Event Theme function

<u>Field Tests – TMDL Development</u>

The first field tests of the PDA/GPS stream assessment method were performed on six benthically impaired stream segments that were slated for TMDL studies in central Virginia. The streams ranged in length from 100 feet to 5000 feet and were located in predominately rural watersheds. Major land uses located in the drainage basins for the streams consisted primarily of forests and moderate grazing and pasture uses.

The surveyors using the method were two Virginia Tech undergraduate students who had been using the paper-based form of the method for eight months before beginning the project.

Neither surveyor had any prior experience with handheld computing or GPS technology. The initial training period consisted of a 10-15 minute overview of the operation of the PDA and GPS unit before beginning the first survey. After the training period, the surveyors performed several problem condition assessments and stream surveys along the impaired segments. The users were instructed to record the data as they would with the paper data sheets and to take photos that illustrated the aspects of the site that they were recording. These filenames given to the photos by the camera were recorded in the database in such a way that they could easily be hotlinked to the data point in a GIS project. As they became comfortable with the PDA/GPS method, the surveyors were encouraged to give feedback on the method in order to improve its operation.

The data collected by the surveyors was entered into an existing GIS database for visualization and analysis. Queried data were exported from CyberTracker into an Excel worksheet. The dataset was then modified for import into ArcView. Unnecessary data resulting from the export process was removed and the replace function was used to add the pathname to the digital image filename so that the hotlink function of ArcView could properly locate the image file. The data were then saved as a delimited text file and added to an ArcView project as

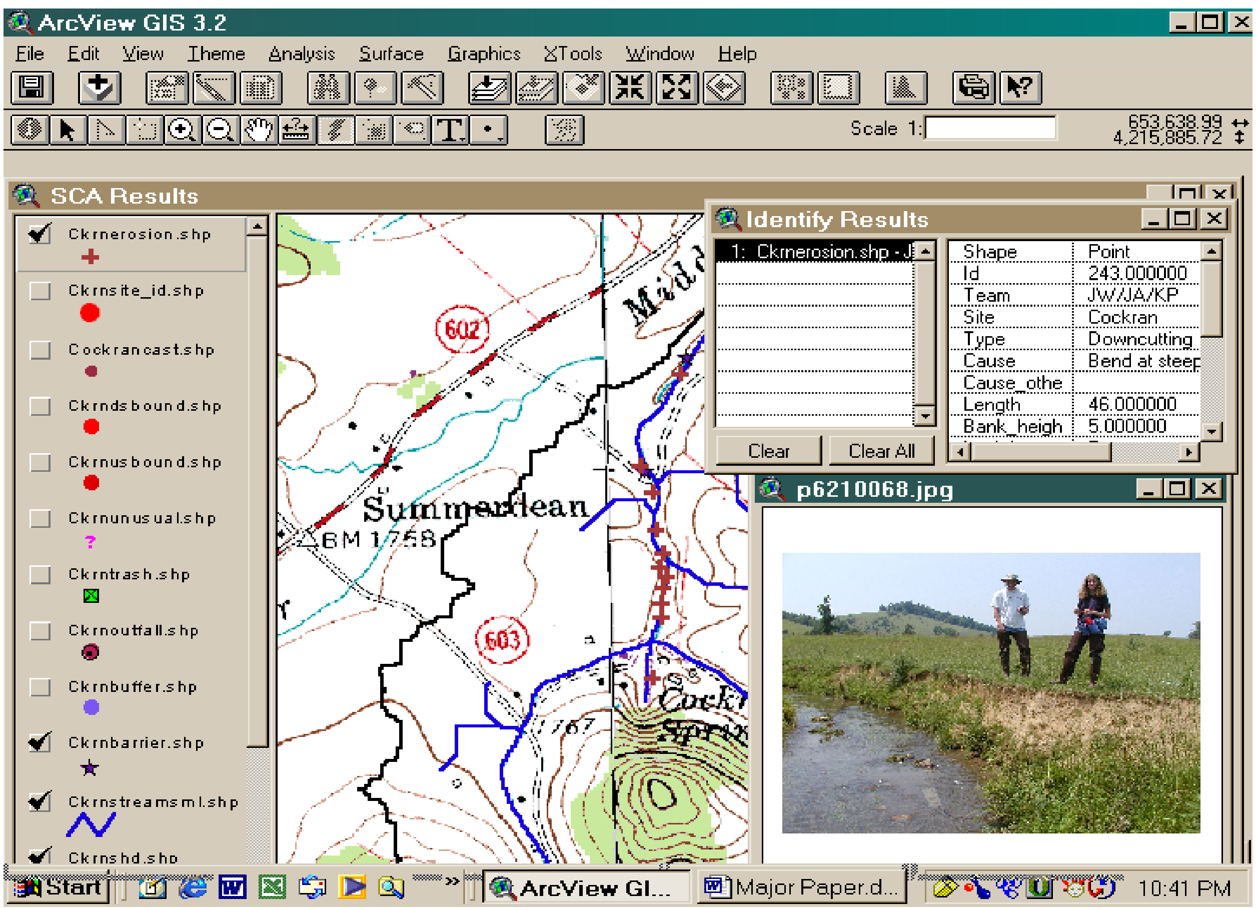

Figure 5.8 – ArcView project resulting from PDA/GPS StreamWalk survey

a table. The "Add Event Theme" function of ArcView was then used to build a shapefile from the table. The datasets were projected to overlay digital USGS topographic maps and each point was hotlinked to its corresponding digital image. The result is a dynamic map that allows you to visualize the location and spatial relationships among the various conditions, the stream and the surrounding land uses, as well as providing a detail record of the specific condition noted by the surveyors (Figure 5.8).

<u>Field Tests – Elementary School Outdoor Classroom</u>

Later tests were conducted with primary school students and teachers at Appalachia Elementary School, located in southwest Virginia. The survey was scaled-down to a 4th grade level by simplifying the terminology, limiting free response answers and developing a more icon-driven interface. The initial survey was conducted on a 100-foot section of stream located near the elementary school. The school is planning to use the stream assessment method to as a tool to fulfill hands-on education requirements that are part of the Virginia Standards of Learning (SOL) legislation. They feel that the combination of the technology and the outdoor classroom activities will provide a great opportunity to provide the students with a unique hands-on learning opportunity. However, the PDA/GPS combination is only one aspect of their approach to environmental education, which also includes outdoor learning stations and many other learning activities. They see it as an effective tool to capture and maintain the interest of the students and get them into the subject matter.

The students involved in the survey had no experience with either stream assessment or PDA/GPS technology. A two-hour training session, covering the use of PDAs and GPS units, as well as the terminology and use of the database was conducted as a field exercise. The students were paired off and each pair given a handheld computer with the simplified streamwalk database. They were then taken to the stream and introduced to the basic concepts of the method, including locating pools, riffles and runs; identifying bottom sediments; and assessing vegetative cover along the stream corridor.

After the outdoor training session with the students, the teachers were introduced to the desktop application for database design and maintenance. The teachers learned the basic functions of modifying the database, importing data from the PDA and performing queries. After another two-hour session, the teachers were comfortable enough with the operation of the program to begin manipulating and maintaining the database on their own.

Chapter Six – Evaluations and Lessons

Many positive comments were made during conversations with the persons involved in both field tests. The teachers at the southwest Virginia elementary school were impressed with how the PDA/GPS technology and the program maintained the interest of the students. Even after the two-hour training session at the school the students were eager to continue surveying the stream. Students were eagerly pointing out and discussing many aspects of the stream, such as pipes, stream shading and bottom types. At the end of the session, they had learned the basic terminology of the assessment, what to look for along the stream corridor and how to operate the PDA/GPS combination.

The TMDL survey team noted that the GPS points on each item would prove useful in describing the locations of problem conditions to people outside of the survey group. The surveyors also enjoyed the reduction in the bulk of equipment necessary to conduct a survey. They had gone from carrying a 4-inch binder full of survey data sheets to a data logger they could carry in the palm of their hand. The data were more efficiently organized with the handheld computer. There were no more survey sheets that mysteriously disappeared or jumped out of order in the data book.

When the survey team returned to the office, they commented on the ease of data entry. After eight months of transcribing data from paper into a computer database, the Hotsync operation and CyberTracker queries seemed incredibly simple. The adaptability of the program surprised the TMDL surveyors. Comments and suggestions on improving the database and the PDA interface were often integrated over night and ready for use with the next survey.

As with any original method of approaching a problem, certain constructive criticisms were also given during the conversations with the users of the PDA/GPS stream assessment method. The biggest obstacle to efficient use of the method was the learning curve associated with the hardware and software. None of the surveyors were experienced with handheld computing. Consequently, they had difficulty operating the PDA at first. This handicap was quickly overcome as users became more comfortable with the system. The desktop software presented another challenge. Most users were familiar with desktop computing and could perform the basic operations of opening the program and Hotsyncing the data into the program. However, many were confused by the CyberTracker desktop program, which was designed in South Africa and requires a different method of interaction than the Windows and Macintosh systems used here in the United States. Many functions that are typically accessed through a toolbar or double-clicking are only available by right clicking or using specific keystrokes. This problem has proven more difficult to surmount, but it is possible to become efficient with the software, as my personal experience with the program shows. I began knowing nothing about the software and have built and maintained the streamwalk database from the beginning. The tutorials and help files included with the CyberTracker software proved very helpful in learning the software. The program is simple enough that training is not necessary. However, a "break-in period" is recommended before undertaking a major data collection project.

Other shortcomings of the method dealt with its operation in the field. The TMDL surveyors commented on the ability of the paper method to allow large groups to assess multiple sites at one time. This was not possible with one PDA/GPS unit. However, if a group had access to multiple units, multiple sites could be assessed simultaneously. Another recurring problem with field operations was the difficultly users had with seeing the PDA screen in the sun. The LCD screen of the PDA was completely washed out in full sunlight. Users coped with the problem by moving to a shaded area to record data or shading the PDA with their body.

Table 6.1 – Pros and Cons of the PDA/GPS Survey Method

Pros	Cons
GPS points on each item	Hard to read in the sun
"The survey moved faster"	Unfamiliar terms
Maintained interest of students	Paper allows multiple surveys at one time
Simple data entry in the office	Hardware/software learning curve
Easier to "keep up with"	
Adaptability	
More efficient organization	

Lessons Learned

As research into the development of a PDA/GPS stream assessment method progressed, several ways of improving and simplifying the process were discovered.

- Carry extra batteries

Long, hot days in the sun can suck the energy out of your batteries as quickly as it does you.

- PDA protection is not difficult

The unit is compact and easy to hold. When conditions get too bad, it can always be placed in a backpack.

- Simplify the terminology

Some words, such as riffle, riparian and gabion, are unfamiliar and confusing to first-time users.

- Simplify the PDA interface

Make the interface as intuitive as possible. Users should not be required to think about the interface.

- Interest is building

Most environmental groups and agency personnel related to the project have expressed great interest in the results and have commented on the applicability of "something like this" to their field of interest.

Epilogue – Into the Future

As handheld computers and global positioning systems become more functional and adaptable, the use of such technology in the environmental management field will continue to expand. The application presented here is only a rudimentary use of the potential of these systems. The equipment and software can be adapted to any paper-based survey methodology. Applications exist in air quality monitoring, water quality monitoring, aquatic biology surveys, and wildlife surveys, as well as the visual stream assessment presented here. Essentially any data collection method, from the simple consumer survey at the local shopping mall, to an extensive ambient air quality survey of the southeastern United States can enjoy the benefits of a GPS/PDA interface. The possibilities are endless.

The incredible trend of technological advancements in the PDA, GPS and digital imaging fields shows no signs of slowing down. In the near future, PDA/GPS survey instruments could be used to catalog data in the field, which is wirelessly transmitted to the office for real-time database updates. Data collected in the field will be available for review and comment in record time. Agency personnel will be able to recognize and react to trends much more quickly and the general public can be kept well informed about recent trends and characteristics in their watersheds. With the development of new and more advanced peripherals, the data collection capabilities of the PDA will expand tremendously. PDA attachments to measure and record water quality, including temperature, turbidity, pH and dissolved oxygen are already available on the market. And that's just the tip of the iceberg…

This research has demonstrated the potential of a GPS/PDA tool in the field of volunteer stream assessment; however applications in other aspects of stream and watershed restoration will soon follow. Agency personnel will use them to collect detailed information on aquatic biodiversity, water chemistry and other parameters to develop a more complete picture of the watershed and the factors influencing its health. Volunteer groups will continue to supplement this data with their assessment of stream conditions and surrounding land uses.

Data from both volunteer organizations and professionals will be integrated into a GIS database where the data can be extensively analyzed and the complex relationships among them can be more fully understood. Data collected by agencies and organizations throughout a large watershed, such as the Chesapeake Bay basin, will be available through an online, interactive GIS. Users will be able to add their own data to the collection, in addition to viewing data collected by others in the watershed. Each participant will be able to visualize trends in his or her data compared to trends in data across the watershed. This will allow for greater public understanding of the complex relationships that make up a watershed and public participation in watershed management on a scale that has never been seen before.