Networked Emplantable Sensors and Web-Based Data Acquisition for Long-Term Environmental Monitoring

John W. Haas, Ph.D.[1], Stephen P. Farrington, P.E.[2]

Abstract: We are working to develop reliable, low cost emplantable sensor packages that can be permanently emplaced in the subsurface using direct push technologies and connected together to provide long term monitoring (LTM) networks. A microcontroller embedded in each emplantable package digitizes sensor output and communicates with a field computer via an RS-485 connection. Sensor identification and calibration information are also stored on EEPROM in the embedded system. The field communications protocol will accomodate over 3000 sensors per network, and wireless linking between field components and from the field network to the Internet is also possible. The field computer can either store acquired data locally or transmit them via any TCP/IP connection to an Internet-accessible host computer running WebDACS™. WebDACS is Applied Research Associates' web-based data acquisition and control system. This system makes sensor data available to users through the familiar interface of any standard web browser. Users can access their data from virtually anywhere they can connect to the Internet. WebDACS generates on-screen plots and tabular output as well as downloadable ASCII files, and provides data security features that include password protection and visibility control. Sensors deployed to date in hazardous waste landfill and agricultural LTM scenarios include pH, ORP, and temperature for water quality monitoring, and volumetric soil moisture, soil electrical conductivity, and temperature for vadose zone soil monitoring.

LTM in the subsurface at contaminated sites is an expensive endeavor, often exceeding the costs of the remediation phase of a clean-up project. Most LTM requirements are mandated by federal or state regulation and can require monitoring programs lasting for decades or more. The primary contributors to LTM costs are associated with labor. Sample collection, storage, preparation, analysis, and reporting can add a significant financial burden to project expense when extended over many years. Monitored natural attenuation is an increasingly important subset of remedial scenarios requiring extensive LTM of a wide range of water quality, nutrient, and contaminant parameters. We have been working to develop low cost, unattended *in situ* monitoring networks capable of providing quantitative data satisfactory to regulatory concerns. Sensor packages have been developed that can be permanently emplaced in the subsurface using cost-effective, direct push technologies (cone penetrometer, geoprobe, etc.). Our goal is to develop sensors for both saturated and vadose zone monitoring applications. Water quality sensors are housed in a patented, 2-inch diameter emplantable (i.e., "direct pushable") chamber that can be pneumatically controlled from the surface to purge or draw water samples for measurement.

[1] Principal Scientist, Applied Research Associates, Inc. 415 Waterman Road, South Royalton, Vermont 05608. Phone: 802-763-8348, Email: jhaas@ned.ara.com

[2] Senior Engineer, Applied Research Associates, Inc. 415 Waterman Road, South Royalton, Vermont 05608. Phone: 802-763-8348, Email: sfarrington@ned.ara.com

The sensors use a low cost, MicroChip™ PIC1400 microcontroller to acquire input from up to six analog sensor channels and communicate with the field network. Each device also stores device-specific calibration information in the memory of an on-board electrically erasable programmable read-only memory (EEPROM) module. Prior to installation, the devices are programmed with identification and calibration information via a PC. Once installed and powered-up, they acquire and report sensor data in response to a command string which includes the device address and is issued over an RS-485 multi-drop serial communication network. A field computer running the data acquisition agent software can either store acquired data locally, or insert it into the web-based data acquisition and control system (Web-DACS) via any TCP/IP connection to the Internet. The field communications protocol can accommodate over 3000 sensors per network site connected over up to a mile of cable, and allows wireless linking both between field components and from the field network to the Internet.

The Web-based Data Acquisition and Control System (WebDACS) provides users with on-demand and user-friendly access to (a) the ability to remotely collect and control acquisition of data from their sensors or monitoring network, (b) a secure but widely accessible repository of geo-spatial environmental monitoring data, and (c) value-added tools for data reporting, visualization, fusion, modeling, or other analyses. The acquired data may include any geo-spatially referenced environmental measurements or process parameters. Functionally, WebDACS is comprised of four main components:

- field-networked sensor packages;
- a database for storing sensor information, data acquisition and control parameters and collected data;
- a software-based data acquisition and communications agent for getting information to and from the field and the database; and
- the browser-based user tools for changing data acquisition control parameters, accessing, viewing, or analyzing the acquired data, or downloading the data for further analyses.

The components run independently of each other but information exchange between them is comprehensive and fully integrated. The components will communicate with each other across a standard internet network. Thus, it is not necessary for all the components to be running on the same computer, although they work together in this fashion as well.

Associated with all data in the database are the geo-spatial coordinates of the sensor or measurement as well as sensor manufacturer, serial number, and calibration information. The central database can be running either on the same computer as the acquisition and control agent or on a remote computer accessed over a TCP/IP network. Currently, WebDACS is implemented using the MySQL structured query language relational database engine. The SQL database can service requests for data from any software capable of performing SQL queries via the ODBC protocol, including ASP, ColdFusion™, PHP, MS Access™, MS Excel™, Symantec Crystal Reports™ and many other applications.

The web browser interface is implemented using web server software and a collection of simple, interrelated web pages that are generated upon request to incorporate recently acquired data.

WebDACS is currently implemented using Apache Web Server with a pre-hypertext processor (PHP) based back-end to create dynamic web pages (i.e., HTML files) on-demand. These pages are formed by the server-side PHP application accessing the SQL server "on the fly" to display the most recent information or time history requested by the user via the web browser. This architecture enables the user to exploit the full power of the monitoring network and logging system, through the simple and familiar interface of his or her own web browser. The system operates on any platform (Windows, Unix, MacOS, etc.) employing a relatively up-to-date web browser, such as version 4.0 or later of either Microsoft Internet Explorer or Netscape Navigator. An example screen shot is shown below.

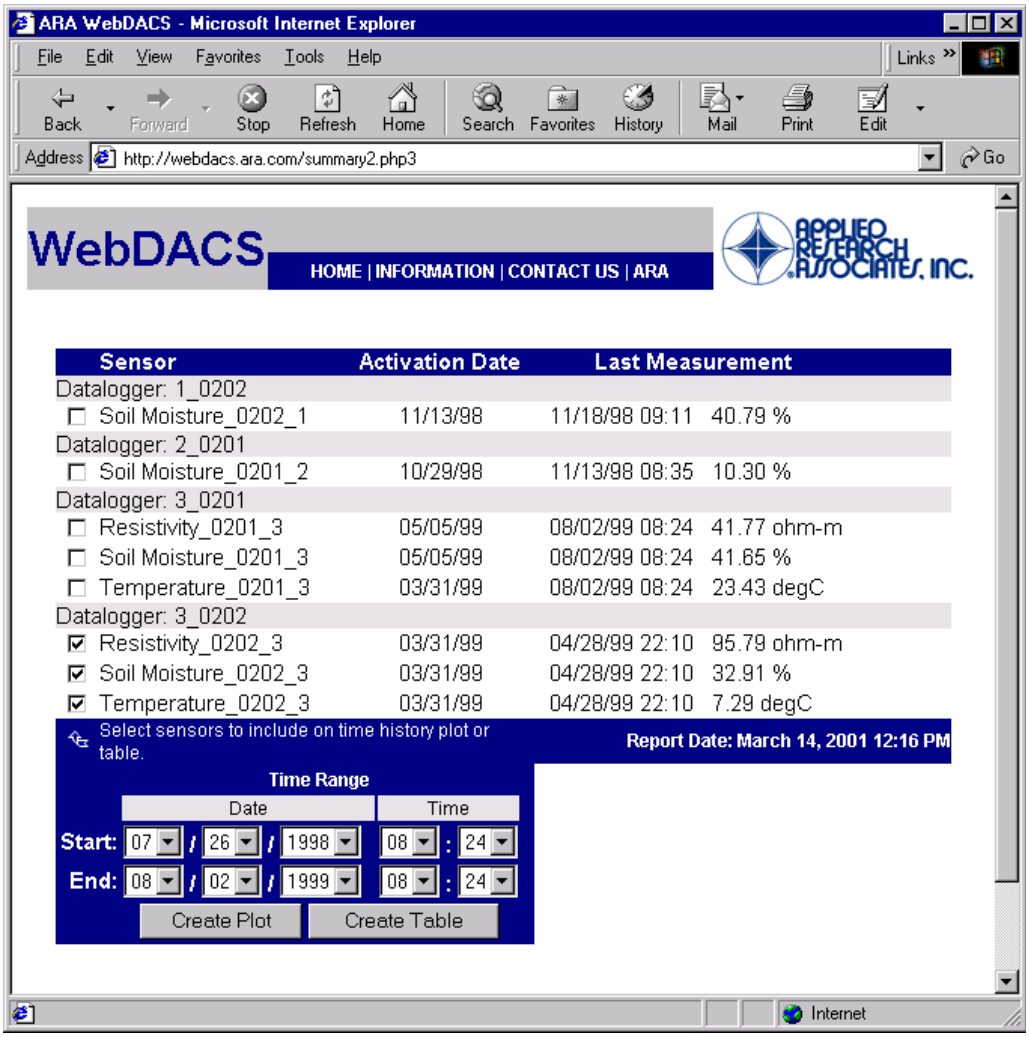

Figure 1. Screen shot of WebDACS sensor summary page. Text entry fields and buttons at the bottom of the page allow the user to generate a plot or tabulation of data from specific sensors selected above over a specified time interval.

Because WebDACS is able to make monitoring data available to users through the familiar interface or any standard web browser, users can access their data from virtually anywhere they can connect to the Internet. WebDACS generates on-screen time-series plots and tabular output as well as downloadable ASCII files, and provides data security features that include password protection and visibility control.