THE TRIAD APPROACH – REDUCING UNCERTAINTY ON ENVIRONMENTAL SITES BY APPLYING MOBILE AUTOMATED DATA CAPTURE AND REAL-TIME EVALUATION

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ABSTRACT

Better, faster, smarter, and cheaper is the goal of the Mobile Automated Data Capture (MADCAP) team working on various tools to capture environmental field data electronically at the point of origin. The objectives align with U.S. Environmental Protection Agency’s (EPA’s) Triad initiative (http://www.triadcentral.org/). The Triad approach consists of three components: systematic planning**,** dynamic work strategies**,** and real-time measurement systems. MADCAP, a collaborative effort between Bechtel National Inc., Idaho National Laboratory, and Bechtel Nevada, Inc., will improve and streamline the current handwritten processes of recording data for assessment, cleanup, and site closure activities at contaminated U.S. Department of Energy (DOE) and Department of Defense (DoD) facilities. The MADCAP team is using current technology developed for Personal Digital Assistants (PDAs), Tablet PCs, and data collection using sensors/detectors to capture borehole logs, field sampling parameters, surface measurements, and environmental health and safety data for direct download into a project database(s) to be analyzed in the field, office, or remotely in real-time via the internet.

MADCAP consists of the following applications and real-time data capture tools: BecLogger©, BecGeoWorks©, Dynamic Real-Time Evaluation and Characterization Tools (DYRECT©), and Web BecGeoParsing©. BecLogger software resides on a PDA or Tablet PC and is designed for collection of geotechnical and environmental data, and follows DoD and DOE technical guide specifications for recording and describing soil and rock for environmental and geotechnical investigations. BecGeoWorks software resides on a Tablet PC and allows for process-driven environmental field collection of observations and measurements, careful sample packaging, handling, shipping and tracking of media samples and wastes using standard defensible procedures. DYRECT consists of hardware/software components that directly capture and process data from sensors or detectors (e.g., radiation, organic vapors, etc.) in the field for real-time evaluation and decision-making. Web BecGeoParsing© is a web portal system being developed and pilot-tested on several remedial investigation sites.

Field data are captured electronically at initial collection, using BecLogger or BecGeoWorks, and DYRECT tools. These data are directly uploaded to a database and merged with other laboratory electronic data prior to analysis. The data set is then queried and manipulated via the MADCAP web portal system to allow management, client and stakeholder access to field and analytical data for analysis, visualization, communication, real-time decision-making and reporting.

The investment in time, hardware, software development and pilot-testing has proven that implementing MADCAP supports Triad by allowing for systematic planning**,** dynamic work strategies**,** and real-time measurement and data evaluation. The added control over data sets has significantly improved data quality and reduced the probability of making an incorrect decision by applying available technology to automate manual processes and improve communication.

INTRODUCTION

Bechtel worldwide is working on numerous and varied projects (e.g., construction, decontamination and demolition, environmental, etc.). The sites worked (i.e., DOE (including INEEL), DoD, foreign sites with characteristics similar to US DOE and DoD, commercial) vary from greenfield to those contaminated with relatively innocuous contaminants to sites contaminated with high levels of radioactivity. Accurate characterization and restoration of these sites is critical to protecting health, safety and the environment, meeting schedule and budget, and making correct environmental and management risk decisions, whether it is for foundation design, environmental characterization or restoration and/or transfer of parcels for redevelopment.

Unforeseen health, safety and environmental risks can be encountered at a site at any juncture during construction, environmental characterization or restoration activities. This is particularly true at DOE and DoD facilities. These sites are assumed or known to be contaminated prior to construction activities or property transfer. New capabilities made available through enhanced development of DYRECT, a real-time data capture and evaluation tool, will provide a means to:

- Protect health, safety and the environment,
- Speedup environmental cleanup activities by reducing schedule and analytical needs (cost),
- Reduce the risk of making an incorrect environmental or management decisions at contaminated or redevelopment sites, and
- Improve the process of verifying sites "clean" prior to property transfer.

Traditional remedial action workplans, for example, dictate the number and locations of confirmation samples following a remedial action. The MADCAP system allows project personnel to collect confirmatory field data at prescribed intervals during the remedial action, identifying localized areas of remaining contamination. The field data is used to focus the remediation efforts to these areas. Additionally, the field data can provide a level of confidence that the confirmation sampling will demonstrate that the remedial action goals have been met.

Savings related to replacing pure manual data entry and transfer of geotechnical and geoenvironmental data is captured through reduced field schedules and analytical costs, real-time data evaluation and timely decision-making. Field applications of MADCAP are presented to illustrate how increased quality gained by reducing errors from manual revisions and review cycles combined with reduced project schedule, and high quality real-time web analyses of data, improves communication and speeds decision-making.

These savings allow technical staff to make better decisions, increase the quality of their monitoring, and produce higher quality reports and investigations, while applying EPA's TRIAD approach. The MADCAP system, allows the use of technology to obtain information on contaminants in real-time for collaborative decision-making.

MADCAP OBJECTIVE

The MADCAP goal is leveraging technology to field operations so that data collected and recorded, using a PDA/Tablet PC/Laptop or sensors, can ultimately be shared over the internet and evaluated by project managers, technical experts, clients and stakeholders to allow for timely collaboration and decision making to support personnel and environmental health and safety, and accelerated cleanup or redevelopment. MADCAP presently consists of five major elements: (1) electronic data capture programs (BecLogger and BecGeoWorks) (2) detector or sensor data capture (selection dependent on material property or chemical characteristics), (3) GPS positioning, (4) database management, and (5) web-based visual data display and analysis. A system may possess all of the functionality; however, may vary in physical configuration, detection capability, and mode of collection depending on the site’s target contaminant(s) and physical characteristics.

The objectives for MADCAP are as follows:

- Protection of health, safety, and the environment,
- Provide high quality, timely field data that feeds directly into the MADCAP system,
- Superior decision-making continuity between the worksite and corporate centers,
- Shorten field schedule and reduce analytical needs (cost reduction) from current baselines to meet cleanup milestones at environmental and construction sites,
- Accelerate the site verification process to establish cleanup compliance level prior to property transfer and redevelopment, and
- Reduce both environmental and management risk of making incorrect decisions at construction or environmental sites.

Advances in mobile technologies and wireless communications allow for incorporating added functionality to the capabilities of MADCAP. Some of those functions include:

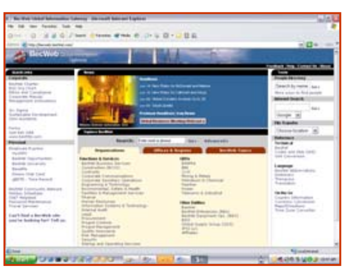
- Achievement of ALARA (As Low As Reasonably Achievable) goals for worker safety by reducing exposure and the chance of exposure to hazardous environments,
- Automated Quality Assurance (QA)/Quality Control (QC) , data validation and filtering,
- Automated mapping and integration with geographic information systems (GIS), and
- Wireless communications, where allowed, for instant transmittal of work progress from the worksite to the office or corporate center.

MADCAP SOLUTIONS

MADCAP mobile technologies and solutions are expanding as various sensors, detectors, radiofrequency devices, and wireless capabilities become more affordable and ubiquitous. Site characteristics and project requirements will dictate a variant of the tools in the MADCAP system to be used at a site. This inherent flexibility allows the configuration of multiple system platforms for sites that exhibit a range of contaminants (i.e., fuels, solvents, metals, and radionuclide). The primary components and representative implementations of MADCAP tools are summarized in Table I: BecLogger, BecGeoworks, Dyrect, BecGeoparsing.

Each of these specific tools integrate GPS and are in use at various sites to improve the process of data collection by improving the mapping, quality, and timeliness of data capture available for immediate analysis. BecLogger is successfully being used to capture borehole logging and geotechnical measurements at Navy environmental sites and at Oakridge Reservation. BecGeoWorks has been designed with the Nevada Test Site field sampling program and is being extended to encompass DOE documentation, permits, and environmental sampling requirements. Dyrect has been successfully used to pre-screen surface soil contamination for uranium, thorium, radium, and Plutonium-238 data at various DOE sites. BecGeoparsing is enabling real-time analysis of borehole logging data from the field directly to management and regulators – additional capabilities are in progress. In addition, MADCAP solutions are adding Radio Frequency Devices (RFID) and Smart Chips to increase the data collection and real-time capabilities. The goal of these solutions is to ensure compatibility and to offer different options pending the requirements for various projects. The ultimate goal is eliminating hand-transcription of data and improving real-time safety and environmental data quality across environmental project sites.

Table I. MADCAP TOOLS

MADCAP Tool	Description	Representative Implementation
BecLogger© 	Geotechnical and geological logging data capture with GPS positioning and wireless capabilities(PDA and Tablet PC)	Bechtel National, Inc. Bechtel Jacobs LLC, Oak Ridge, TN • Borehole logging • Environmental data capture • Direct upload to data management system
BecGeoWorks© 	Geoenvironmental and Health and Safety data with GPS positioning, wireless capabilities; checklists, workplans, and standard operating procedures (Tablet PC) (Comprehensive documentation to assure adherence to Price Anderson Act Amendment (PAAA))	Bechtel Nevada, Inc. • Onboard documentation • Environmental sampling • Electronic record keeping • Direct upload to data management system • BecLogger compatible
DYRECT© Sensor Tools 	Real-Time data capture, processing and evaluation with various sensors/detectors, GPS positioning and wireless capabilities	CH2MHill Mound, Inc., DOE-Ohio Fluor Fernald Inc., DOE-Ohio • Radiation detectors • VOC detectors • Geophysical properties • BecGeoWorks compatible
Web BecGeoParsing© 	Worldwide Web-based – GIS enabled, real-time analysis with standard applications	Bechtel Corporate eEngineering Initiative Pilot Testing of borehole logging data in real-time
Technology Enhancement	Radio Frequency Devices (RFID), Smart Chips, with wireless and computing technology continuously adding components to MADCAP tools	

MADCAP AND THE TRIAD APPROACH

MADCAP objectives are synchronous with EPA's Triad Approach:

- systematic planning,
- dynamic work strategies, and
- collaborative and timely decision making.

Figure 1 summarizes the MADCAP solutions, sensors, and technology components that work in harmony with the Triad approach for reducing uncertainty. The first Triad element, systematic planning, is critical in setting the stage for the ultimate goal of confident environmental decision-making, with technically sound and defensible decision points. In the planning stage, the technology tools used must support the data required for expected site specific constituents and conditions to allow for real-time, in the field decision making. The technology must also gain acceptance amongst all the stakeholders involved (e.g., community, special interest groups, regulators and customer).

The adoption of new technology dictates that initial demonstration or pilot testing be conducted ahead of the full phase of the fieldwork to 1) identify and correct unforeseen problems before instituting a new process, and 2) increase the confidence (certainty) of the stakeholders to allow for real-time in field decision making. In this manner, the planning and dynamic work strategy phase can include lessons learned and best practices from the demonstration or pilot before full implementation of the investigation. A simple example is familiarizing users with a mobile computer device: long-term field users may need to become familiar with the use of PDAs or Tablet PCs functions/stylus, battery limitations and other suggested best practices (Table II).

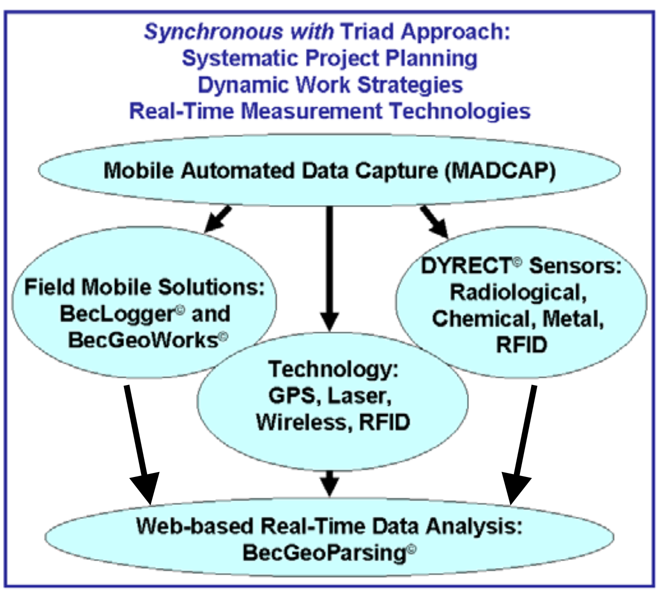


Fig. 1. MADCAP components synchronous with EPA's Triad Approach

In the same manner, systematic planning also allows for maximum utilization of technology that may lead to development of additional site-related quality control enhancements and alert systems (Figure 2). For example, for routine monitoring of groundwater wells at environmental sites, it is a common standard operating procedure to carry field guidance documents (e.g., health and safety plan, activity hazard analysis, hazardous work permits, workplan, standard operating procedures, database printouts of historical contaminant concentrations at the site, etc), while working in the field. This present process is not only extremely cumbersome, but can lead to incomplete record keeping and personnel tracking.

MADCAP's BecGeoWorks tool synchronizes and uploads all documents required prior to initiating fieldwork to the TabletPC for easy access, reference and comparison by the field crew. It automates the former process thereby reducing the physical volume of documents carried into the field. Site-specific alerts (e.g., health and safety, well conditions, expected groundwater conditions, etc.) can be preprogrammed in advance of the fieldwork to alert the crew to field conditions and calculate unacceptable variance from the historical field readings or groundwater parameters (e.g., pH, Eh, temperature, field screening measurements) to allow the user to adjust to or verify and confirm anomalous readings.

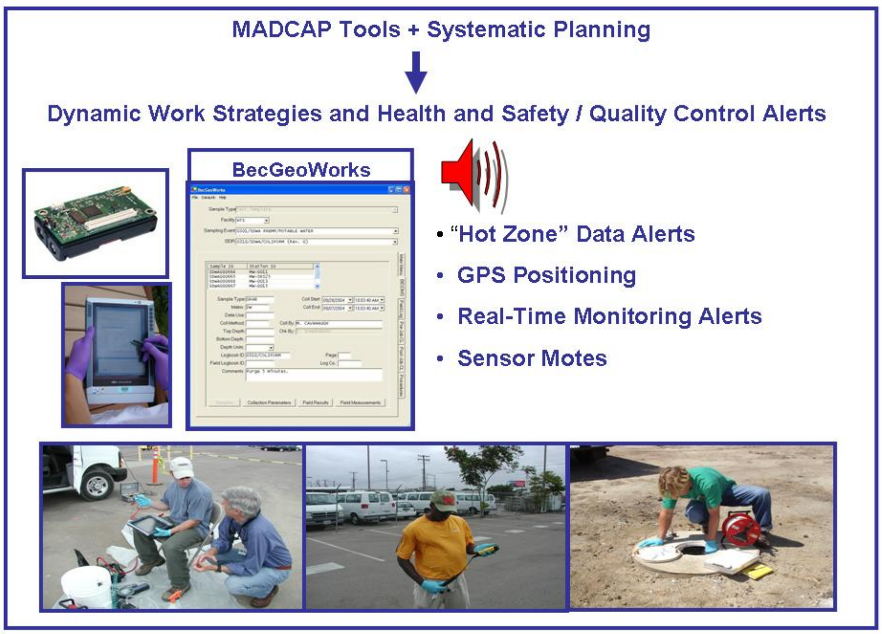


Fig. 2. MADCAP tools for health and safety/quality control alerts

In addition, health and safety alerts can be pre-planned in the strategy sessions and at readiness reviews prior to field activities (Figure 2). For example, previously investigated "Hot Zones", historic analytical data, or health and safety air monitoring criteria can be pre-planned in MADCAP's BecGeoworks and linked to GPS coordinates to warn personnel that they are in proximity of a health and safety alert area and should take specific precautions.

Other examples of the importance of the systematic and strategic planning phase is that known boring locations and cross-section zones can be delineated, planned and programmed ahead of time to ensure acquisition of high quality data in the form that the client or agency requires to view or analyze. Hence, as drilling proceeds, cross-sections can be built and displayed in real-time. This simple method of real-time data analysis allows stakeholders to make timely decisions regarding subsequent phases in the dynamic working strategy of the site investigation (e.g., install monitoring wells at different locations or zones). Similarly, using DYRECT sensors, allows continuous long-term monitoring of environmental conditions keeping in mind sensitivity parameters of the technology tool (e.g., determining the resolution of the display and zones mapped and contoured with GPS positioning instruments).

Hence, using Triad principles and MADCAP tools, real-time decisions can be made based on selectivity, sensitivity, and precision for enhanced characterization (and remediation) to "manage decision uncertainty" [1]. Time and analysis invested in the pre-planning phase determines how well the dynamic work strategies can guide an investigation and result in the reduction of uncertainty prevalent in environmental and management risk decisions. Although the Triad approach is not a regulatory driven initiative, but a technical initiative, it results in a scientifically sound and cost-effective approach that makes sense for all stakeholders.

The key to the Triad Approach is to have a focused Quality Control Protocol, the rationale which should be written into the dynamic workplan. The collection of real-time data allows for timely development of the conceptual site model to optimize decisions on the need for samples, direction, location and depth of sampling, possible addition or reduction in number of groundwater monitoring wells, review of analytes, as well as health and safety requirements for the site. The key to MADCAP is that real-time data capture drives not only the characterization and remediation of a site with resultant cost savings, but brings worker health and safety issues to the forefront by increasing the certainty that correct safety decisions are made during the planning phase. The dynamic work strategy and timely decision making processes rely upon the continuous output of the real-time systems in the field to provide field workers, project management personnel, and stakeholders with up-to-date site information and documentation to protect the health and safety of construction workers and the environment. The advantages to the combined MADCAP data model with the Triad Approach is that it leverages technology to improve standard operating procedures and best work practices, thereby lowering the environmental and management risk and liability associated with work at construction or environmental management sites.

MADCAP REQUIREMENTS AND LESSONS LEARNED

The development of MADCAP solutions requires the following hardware, software, and technology capability, summarized in Table II.

Table II. MADCAP Requirements

Hardware Requirements:	Low-cost, field durability, field portability, back-lit screens; Mobile/Pocket PC 2003; Secure Digital (SD) Card backup; commercial GPS link capability; real-time sensor and mote capability
Software Requirements:	Work-Process Driven; Microsoft®.NET Compact Framework development (C#); ASTM-guided menus; Standard Operating Procedures; Association of Geotechnical and Geoenvironmental Specialists (AGS) format; Extensible Markup Language XML; scalability to PDA and Tablet PC; digital signature and tracking capability (change history); multiple database location requirements
Additional Requirements:	Minimal (30-minute) training rule; wireless and synching dual capabilities for upload

Lessons learned and best management practices resulting from field pilot testing and implementation of MADCAP are summarized in Table III:

Table III. MADCAP Implementation Lessons Learned and Best Practices

Requirements	Best Practices
Battery Requirements	Best practices suggests a second mobile device charging as backup for any field operation due to the possibility of battery loss or device failure. The current Pocket PC and Tablet PC are high battery consumable devices. A maximum of 4 hours of continuous field operation on each device battery was realized. This was mitigated through the use of a power inverter to keep all devices and peripherals charged.
Backup Requirements	Multiple saves to hard drive and SD card allows for swaps of the memory cards between duplicate mobile devices. Common field circumstances that may require swaps are: low battery, device failure, fall hazards, severe weather conditions.
Training Requirements	Training requirements for the software should be minimal. However, use of the device itself may require training. For example, familiarity with the pen stylus on the Tablet PC should be considered as part of the pre-planning strategy for field data collection.
Peripheral Requirements	Best practices suggest upload of data to main server or project database on a daily basis. Peripheral hardware devices are recommended for field use: mobile printers, wireless cell phone modems, or 802.11x wireless setup for upload to office is highly recommended. In DOE or DoD areas of high security, where wireless devices are prohibited, the data can be uploaded and/or printed from an offsite location on a daily basis.

CONCLUSION

The vision of the MADCAP system is to provide the field personnel (i.e., engineer, geologist, construction worker, etc.) with the tools (e.g., PDAs, Table PCs, wireless cell-modems, digital cameras, etc.) that support electronic data capture, high quality data management, and prompt data evaluation and interpretation. These tools will connect project managers, fellows, technical experts and clients via a web-portal system. Solutions derived from implementation of MADCAP and the Triad Approach will reduce project costs by minimizing non-value added tasks,and increased quality, through improved data accuracy, consistency, and completeness.

The MADCAP tools are growing and evolving as technology is making smart chips and RFID sensors more practical and affordable. Keeping in mind the Triad principles of selectivity, sensitivity, and precision along with the systematic planning, dynamic work strategies and real-time measurement systems, these technology advances are not only making the concept of the Triad Approach more practical, but a requirement. The MADCAP team believes the environmental industry should be proactive in utilizing this technology to:

- Be protective of health, safety and the environment,
- Reduce uncertainty,

- Lower environmental and management risk,
- Improve QA/QC, and
- Speedup sound decision making.

The resultant cost saving could be applied to accelerating cleanup and redevelopment/reuse of properties.

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REFERENCES

1. Crumbling, Deeana M., 2004, White Paper: Summary of the Triad approach, March 25.