Automated Web-Based Remediation Performance Monitoring and Visualization of Contaminant Mass Flux and Discharge

Dr. Mark Kram, Cliff Frescura, Brian Kahl and Jasmine Showers

GROUNDSWELL
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ABSTRACT

Conventional environmental monitoring, data processing and reporting methods are expensive, labor and resource intensive, time-consuming and often inaccurate. An innovative project management platform was developed for integrating sensors, telemetry, geographical information systems, models, and geostatistical algorithms for automatically generating contour maps, three dimensional images and time stamped renderings of sensor attributes and multivariate analyses through an Internet browser. More specifically, algorithms converting sensor derived head and solute concentration values allow for automated multi-dimensional visualization and monitoring of mass flux and discharge over time for evaluating groundwater remediation system performance and contaminant discharges from aquifers to surface water receptors. Life cycle costs and carbon footprint were reduced due to the elimination of energy and labor expenditures associated with transportation, data collection, laboratory efforts, report generation, travel, and information dissemination. A brief summary of a successful demonstration of an automated resources management application is presented.

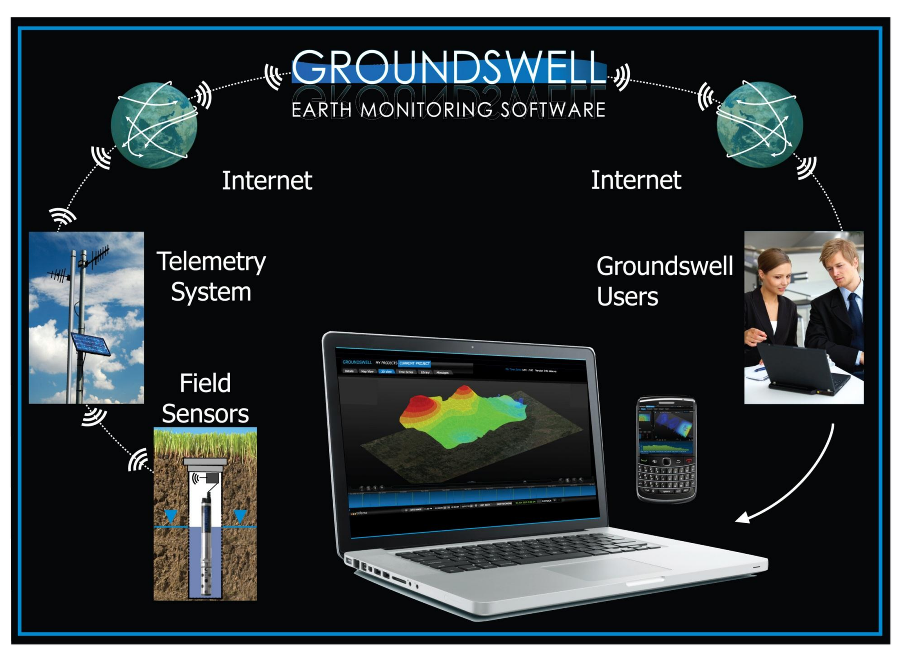
BACKGROUND

Improved monitoring approaches are urgently needed for faster, less expensive and more effective assessment, restoration and resource management.

A typical groundwater sampling event requires sample collection, sample analysis, data processing, and report preparation to allow for decision-making and appropriate response. This sequence often requires 3 to 6 months to generate a final report for each sampling event. For water quality investigations, this wasteful process is exacerbated by the fact that organic contaminant sample integrity is often compromised during collection, transport and storage. Conventional monitoring approaches are simply not capable of providing real-time analyses of site conditions to enable critical decision-making and contingency response. Recent technological advances have resulted in new opportunities for fielding automated devices capable of remotely measuring chemical and physical properties and characteristics through a centralized project management platform. Robust automated sensors are now available for monitoring water level, contaminant concentrations, remedial performance, and resource sustainability

TECHNOLOGY DESCRIPTION

The figure below displays the general system components for the patented environmental and resource monitoring platform. Field sensors are linked to data loggers and telemetry systems, which transmit the data to a remote location where data are automatically processed according to the user needs (e.g., contouring, model update, multivariate analyses, etc.). The system can be customized to automatically generate reports, and to trigger alarms, pumping rate adjustments and emergency response plans. Sensors can be deployed in groundwater, surface water, vadose zone and air. Data processing and management are automated, as is organization of the visualizations (e.g., single time stamped graphics, multi-graphic tiles, animation loops, and export capabilities). Since the platform is web-based, external software is not required, and access is through a password-protected browser, thereby enabling users to monitor sites from any location or device with Internet connection.



Automated monitoring parameters include: vapor intrusion VOCs, CH_4, TCE, Cr(VI), CCl_4, nitrate, atrazine, chlorophyll, water level, temperature, pH, conductivity, salinity, Br^-, Cl^-, NH_4^+, DO, ORP, oceanographic attributes.

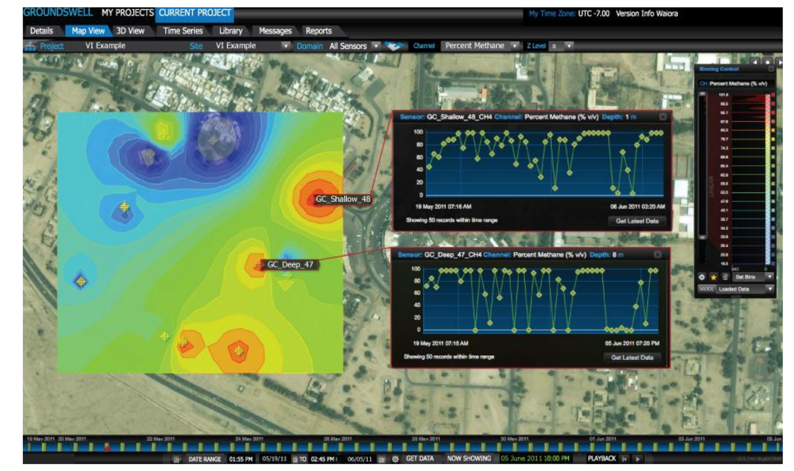
The sensor-based automated monitoring and reporting platform can perform the following:

- Generate 2D/3D/4D contour maps of sensor parameters and multivariate results;
- Calculate and monitor distributions and cumulative groundwater basin storage changes through time;
- Track contaminant plumes and remediation progress (e.g., concentration, hydraulics, mass flux and discharge);
- Assist with model calibration and remedial optimization.
- Can serve as a centralized "hub" for managing multiple sites simultaneously.

CONTOURING

Automation through the use of sensors, geospatial processing and rapid visualization and archiving allows for much more temporally dense evaluations and superior decision making. Contouring applications include water quality, air quality, water supply, oceanography, agriculture and homeland security. The first image below presents a time-stamped distribution of percent methane sensor data along with user engaged time series analyses and animation playback tools for spatiotemporal context.

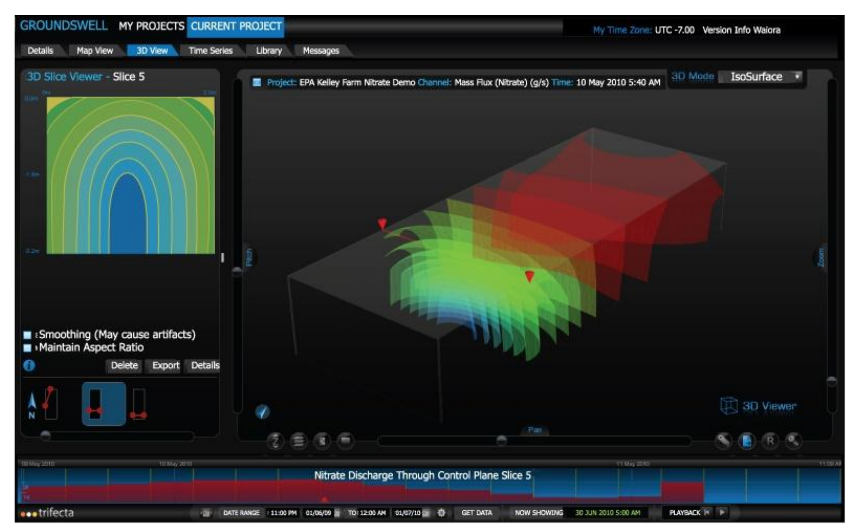
The decision making process can be improved by instantly viewing and analyzing solute distributions and time series charts from selected plume locations.



When practical, virtually any type of sensor that is coupled with telemetry can be integrated into the automated contouring platform. Multivariate analyses and visualizations are also automated. 2D and 3D renderings and playback loops allow for detailed temporal and spatial understanding (e.g., superior conceptual site models), and result in more defensible decision making capabilities. With some applications, decisions can be automated. For instance, if thresholds for sustainable groundwater extraction are exceeded, not only will the platform record this observation, but controllers can be engaged to reduce the extraction rate of wells pumping unsustainably.

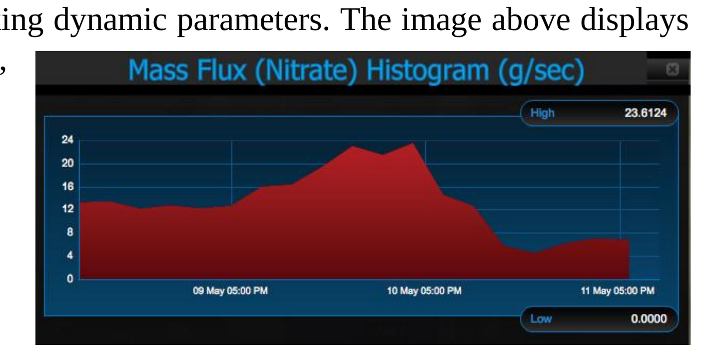
Static and live data can also be "blended". For instance, initial site characterization and laboratory results can be entered into the platform, then later augmented with sensor readings. A useful example is represented by groundwater contaminant characterization and long-term monitoring applications. Following initial Triad based characterization and well installation, sensors can be deployed in monitoring wells to evaluate hydraulic and contaminant fluctuations as well as remediation performance. A comprehensive archive is automatically generated and made available to project collaborators every time new sensor readings are recorded.

FLUX-BASED REMEDIATION PERFORMANCE MONITORING



Monitoring mass flux and discharge over time will lead to superior compliance strategies, optimized remediation approaches, and reduced exposure risk.

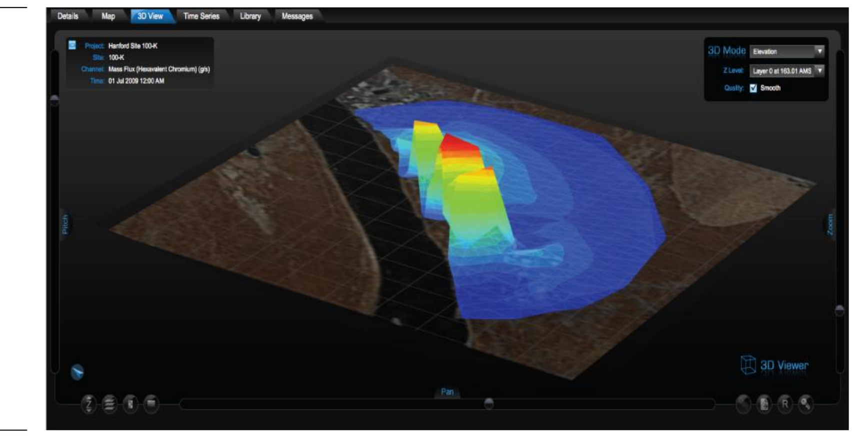
Integration of near real-time sensor data processing capabilities for rapid mass flux distribution assessment represents a significant cost-saving development. Mobile mass characterizations can be used to evaluate source strength and potential risk to receptors (Suthersan *et al*., 2010). When hydraulic head values are integrated with temporally consistent solute concentrations, it becomes possible to determine the mass flux distribution at a site, as these are the only two dynamic components within the flux calculations (Kram *et al*., 2008; ITRC 2010). Hydraulic conductivity values can therefore be blended with sensors tracking dynamic parameters. The image above displays mass flux distributions generated as part of an EPA ETV project, where incoming sensors monitoring head and nitrate concentration resulted in flux model updates. Mass discharge through user-selected transects is also derived and used as a quantitative remediation line-of-evidence and performance metric. The image to the right demonstrates one such performance metric, a histogram of mass flux over time.



MASS FLUX-BASED REMEDIATION CASE STUDY

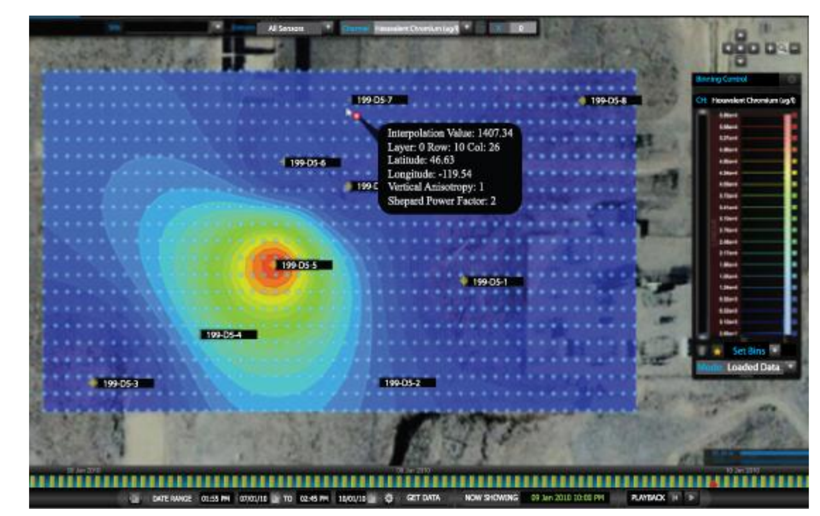
A pilot demonstration was performed at a US DOE facility with historical contaminant releases and ongoing remediation efforts by the Columbia River in Hanford, WA (Kram *et al*., 2011). The selected site was ideal for the demonstration because an automated data-collection network had been deployed, operational large-scale pump-and-treat groundwater remediation systems are in operation, and the site contains a Cr(VI) contaminant plume from historical releases. This demonstration of web-based hydrogeologic management applications was focused on long-term automated contaminant plume monitoring, flux-based remediation performance monitoring, evaluation of groundwater and surface water interactions, and upload of historical data. Most importantly, mass discharge through a control plane was monitored and visualized in an automated web-based configuration. This approach can be used to evaluate historical trends, to track contaminant exchanges between groundwater and surface water in the hyporheic zone, and to establish and monitor remediation performance metrics and compliance strategies. The image below displays a 3D view of the distribution of relative mobile Cr(VI) mass adjacent to the Columbia River.

Targeting areas of high mass mobility for removal or hydraulic control can effectively reduce risks and lead to optimized restoration.



MODEL CALIBRATION

All predictive models, regardless of medium, require calibration to allow for accurate projections of geochemical and physical conditions and to meet other useful objectives such as remediation design. Significant labor and financial resources are allocated to modeling, yet calibration remains a key challenge. Historical water level data is often used to generate and calibrate predictive groundwater transport models. However, these can often be misleading, data starved, and rarely reveal much about detailed distributions of hydraulic conductivity or site specific fate related qualities of water bearing zones. To address these types of challenges, an interpolation tool has been developed to allow modelers to compare predictions to observations. The image below shows measured and interpolated Cr(VI) concentrations for a selected time step. This data can be exported in csv format to calibrate predictive models.



Measurements and interpolated estimates reported over the simulation date ranges can be readily accessed for comparison with predictive model output.

BENEFITS

- Effective use of professional resources
- Continuous automated monitoring, processing, reporting and archiving
- Convert raw data to conceptualizations, reports and decisions in seconds (as opposed to months)
- Centralized, remote, multi-site web based project management
- Superior modeling results and decisions
- On-demand access to all historical and live information via web connection
- Reduce project energy requirements and carbon footprint
- Logistics reduction (permitting, security passes, report generation, labor, analytical, etc.)
- Reduce liabilities (automated alerts, responses, legal archive)
- Optimize remediation via live reporting to trigger rapid amendment adjustments
- More focused remediation goals and effective risk reduction
- Significant time and cost savings
- Scalable to a site, facility, region, national, or global scope
- Secure password-protected access
- Consensus based analyses (share images, reports, webinars)
- Software downloads are not required, access while on travel

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Groundswell Technologies, Inc.
136 W. Canon Perdido St., Ste. C
Santa Barbara, CA 93101
805-899-8142
www.GroundswellTech.com
sales@GroundswellTech.com

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