LONG-TERM MONITORING OF WATER RESOURCES WITH UNDERGRADUATE STUDENT COLLABORATORS

Doss, Paul K., Feldhaus, Aaron, Ford, Chanse M., Stephens, Michael, & Chambers, T. Bryce, Geology & Physics, Univ. of Southern Indiana, 8600 Univ. Blvd, Evansville, IN 47712, pdoss@usi.edu

University of Southern Indiana
Pott College of Science, Engineering, and Education

Abstract:

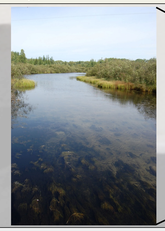
The need for long-term monitoring of ground and surface water resources is well established. Baseline water resource data are prerequisite for resource management planning, quantifying resource extraction and reserves, detecting environmental change, monitoring ecosystem transformations and degradation, and identifying the impacts of local, regional, and global climate change. Moreover, long-term monitoring of water resources is particularly well suited as a research inquiry to be integrated within undergraduate programs in geoscience, hydrogeology and environmental science.

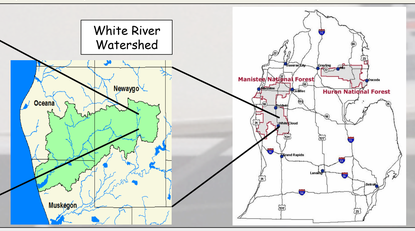
By definition, undergraduate students engaged in long-term water resources monitoring are exposed to the formulation of objectives and the related justifications of timely and relevant environmental research. Further, the students directly apply the concepts learned in the classroom and gain experience examining high resolution data that respond to both natural and anthropogenic stresses, display seasonal and longer variability and trends, and are easily combined with correlative data to be displayed graphically for visual examination. Long-term data also require quality assurance evaluation, statistical interpretation, and archiving. And importantly, these students will use and gain experience with state-of-the-art technology, instrumentation, modeling, and testing methods that prepare them well for the workforce and further study. Finally, students have the opportunity to prepare and submit research proposals for funding through grant programs targeted to undergraduate investigators.

Undergraduate students at the University of Southern Indiana have been successful collaborators and grantees on long-term hydrogeological monitoring research for many years. Research projects include a Pennsylvanian sandstone aquifer that responds to several stressors including barometric change, Earth tides, and reduced groundwater extraction. Students also monitor water resources in Manistee National Forest, Michigan, in support of resource management and protection efforts. Research targets include assessing the potential threat of commercial groundwater extraction to aquatic resources of the forest and quantifying hydrologic change as a result of savannah ecosystem restoration on forest land.

Introduction

Long-term monitoring of water resources requires no additional justification. Large-scale modeling of natural systems, to forecast future conditions and trends, demands long-term and large data sets for construction and testing (Feinstein et al, 2004). In many cases, temporal trends of aquatic system contaminants and nutrients display delays in responses, necessitating data sets that span decades (Burt et al, 2008). And as so clearly stated by Taylor and Alley (2001), "Long term data are fundamental to the resolution of many of the most complex problems dealing with ground-water availability and sustainability" and "significant periods of time—years to decades—typically are required to collect water-level data needed to assess the effects of climate variability, to monitor the effects of regional aquifer development, or to obtain data sufficient for analysis of water-level trends."

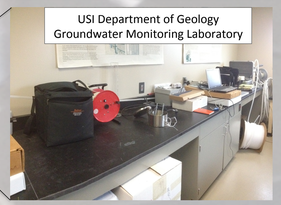




Long term monitoring in two Geologic Settings

Two field sites are used for long-term monitoring of water resources with undergraduate student collaborators from the University of Southern Indiana. Groundwater dependent ecosystems comprising important trout and salmon habitat are investigated in the Manistee National Forest of Michigan (above). Two distinct sites in Manistee NF include shallow and deep upland and wetland piezometers, streambed piezometers, a stream gaging site, drilled wells, and a rain gage. At least six of the piezometers collect continuously recorded (hourly) water level data.

In Southwestern Indiana (below), the Pennsylvanian Inglefield Sandstone aquifer is used for domestic supply in Vanderburgh and Posey Counties. Long-term monitoring is conducted in the USI Groundwater Monitoring Laboratory on campus that houses a deep (33.5 m) and shallow (18.3 m) piezometer nest installed in the Inglefield Sandstone. Pressure Transducers and Data Loggers for each well record water levels on hourly intervals, although one recent student project collected data at 1-minute intervals.



USI Department of Geology Groundwater Monitoring Laboratory

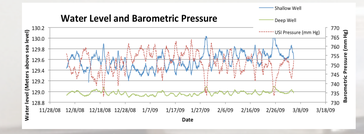
"KILLING SEVERAL BIRDS WITH ONE WET STONE!"

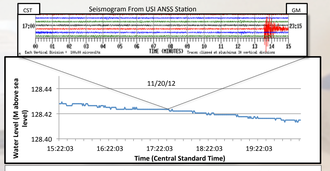
Long-term monitoring is particularly well suited to an undergraduate-centered research program. The educational benefits of these sites and research efforts are the priority, but data targeted to several important resource management objectives are also obtained.

Monitoring is foundational to any environmental research question: explicit objectives have to be established and the effort must be justified, basic hypotheses on system behaviors are developed and tested, and large data sets must be collected, checked for quality assurance, and displayed effectively. The basic application of these scientific protocols in long-term monitoring efforts generates useful resource management information, and trains our Earth scientists in methods and approaches that they will use in the future, likely in "finer scale" research inquiries. Finally, the long-term monitoring research effort can benefit tremendously when undergraduate students are mentored through proposal writing exercises for sources of funding available for student research. Many state-of-the-science instruments deployed in these monitoring efforts have been obtained with funds generated in undergraduate student research proposals. That equipment stays dedicated to the research and monitoring efforts even after those students move on to the work force or graduate studies. Numerous sources of funds, targeted exclusively to undergraduates, are available for use on research. Disciplinary societies such as GSA, AEG, NGWA, the American Chemical Society, and AGU all have money available for undergraduate students. Further, many colleges and universities have funding explicitly for undergraduate research. Of the 14 institutions that responded to an "informal survey" by the Council on Undergraduate Research in 2008, only 1 answered "not really" to the question—"Does your institution provide money to support student research/creative activity?" (CUR--http://www.cur.org/resources/funding_opportunities/)

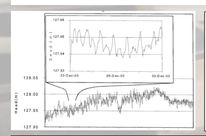
LONG-TERM MONITORING: SOUTHWESTERN INDIANA SANDSTONE BEDROCK AQUIFER

The Inglefield Sandstone Aquifer forms a locally important resource that is subjected to a variety of natural and anthropogenic stresses. Monitoring in this system is focused on water resource changes resulting from land-use and water use modifications. Further, long-term monitoring permits aquifer characterization and identification of stressor impacts to the natural system. Specifically, this aquifer responds to barometric influence, earth tidal influences, and a recent decrease in demand on the groundwater resource due to expansion of the public water supply.



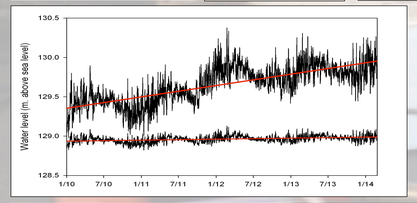


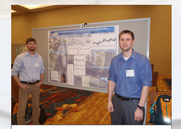
Hydrograph from WMW during M 3.6 Earthquake near Mt. Carmel, IL.



Above—Water levels in the sandstone display a high barometric efficiency (B.E. = 0.93), but also respond to Earth tide stresses (left). B.E. responses are attributed to rigid sandstones locally, and tidal responses are attributed to distal shales & siltstones.

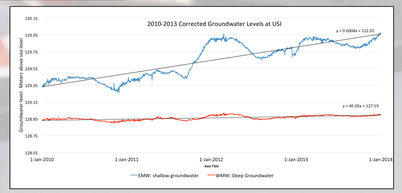
Above--Hydrograph of very-high resolution (1-minute) water level data. A near-field earthquake, 55 km (34 mi) NE of the USI Groundwater Monitoring Lab on 11/20/2012 was felt on the USI campus, but did not produce a measurable response in water levels. Of six near- & far-field earthquakes recorded by the on-campus, ANSS seismometer during the study, no measurable responses in water levels were detected.





A. Feldhaus & M. Stephens at IN Academy of Science: long-term monitoring of sandstone aquifer.

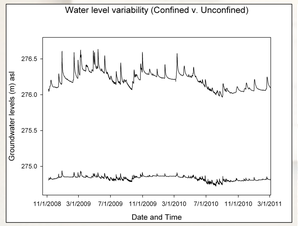
Above--High resolution, long-term water levels in the bedrock aquifer display a vertically-downward gradient, the high degree of variability generated by barometric & earth tide responses, seasonality, annual cyclicity, and different long-term behavior of the shallow aquifer (upper plot) and deep aquifer (lower plot).



Right--After removal of the barometric influence, true potential fluctuations of the deep and shallow aquifer are more readily observed. The rising trend of the shallow aquifer is likely due to decreased domestic groundwater usage commensurate with expansion of the local public water supply system that uses surface water (Ohio River).

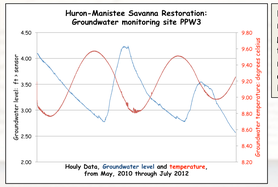
LONG-TERM MONITORING IN MANISTEE NATIONAL FOREST

The ultimate goals of the Manistee monitoring is to provide baseline data from which environmental change by any number of potential stresses can be detected. Parts of the forest are facing potential threats of groundwater resource extraction, ecosystems are slated for transformation and restoration in several forest areas, and predicted climate change may alter the current water budget across ecosystems within the forest. Knowledge of recharge areas, historical water level fluctuations, and water-quality monitoring can provide relevant data for source-water protection of aquatic resources (Alley et al, 1999).



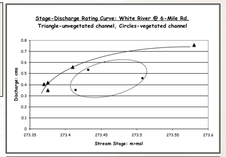
Left—Long term water level data from a riparian wetland site along a headwater stream in Manistee National Forest. Upper plot is upland groundwater level, lower plot is sub-peat, confined sand in the riparian corridor. Stream reach is adjacent to a proposed site for commercial groundwater extraction.

T. Bledsoe, W. Ellis, & M. Bengert in Manistee NF: Long-term monitoring for environmental change



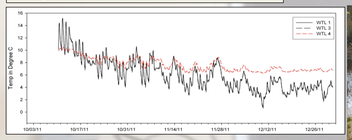
Left– Seasonality in high-resolution, long term groundwater level and temperature data from a monitoring well in an area of ecosystem restoration in Manistee National Forest.

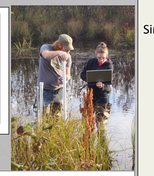
Doss with Chanse Ford in Manistee NF: GW seepage and sustainability of streamflow.



Above—development of a stage-discharge rating curve for a headwater reach of the White River in Manistee National Forest. Rating curve is not robust during late summer months when channel becomes heavily vegetated, raising stage and reducing streamflow velocity.

Below--Input data for thermal modeling of groundwater discharge to headwater stream in Manistee National Forest.





C. Gravemier & J. Heighton in Manistee NF: thermal modeling of streambed groundwater discharge

B. Chambers in the USI GW Monitoring lab: influence of seismicity on bedrock GW levels.

Direct and Quantifiable Educational Outcomes of Undergraduate Student Collaboration on Long-term Water Resources Monitoring Research

Since 2005 (last 10 years):

- 14 undergraduate Research Assistants; 100% employed in field of study &/or funded graduate studies
- >25 credit hours of GEOL499 completed (Undergraduate Research in Geology)
- >10 successful, competitive Undergraduate Research Grant proposals (RISC & Endeavor! Programs)
  > $20,000.00 funding
- All students are co-authors. Published >15 abstracts and peer-reviewed manuscripts (GSA, IAS, NGWA)
- Two external awards for Outstanding Undergraduate Student Research (GSA):
  (Curtis-Robinson & Doss, 2006; Heighton, Gravemier, and Doss, 2012)
- Two internal (USI) awards for undergraduate research (The Barnett Research Award)
  (Curtis-Robinson & Doss, 2006; Inkenbrandt, Doss, Pickett, and Brown, 2005)
- Direct student involvement in de-briefings with resource managers from the National Forest Service

Summary and Recommendations:

Long-term monitoring of water resources and undergraduate geoscience education is a relatively simple pairing that provides unique benefits to students, undeniably serves the research effort, and ultimately provides data that is relevant for resource management. The necessary facets of designing and implementing a long-term monitoring strategy form the foundation of any environmental research. Undergraduate students as collaborators in long-term monitoring learn research techniques that can be applied to future projects, work with state-of the art instrumentation that make them better suited for the workplace or future graduate study, and generate valuable data for resource management. And if that weren't enough…the research and monitoring effort benefits from the regularly updated, enthusiastic student personnel, the potential for greater instrumentation from student funding sources, and the visibility gained from student authors on research presentations and publications.

Long-term monitoring of numerous environmental variables, particularly water resources, can be dramatically enhanced by "harnessing" a network of undergraduate geoscience researchers. Moreover, in many cases, a monitoring program can be at least partially funded by grants available to undergraduate students.

Acknowledgments:

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