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The JUPITER (Joint Universal Parameter IdenTification and Evaluation of Reliability) project builds on the technology of two widely used codes for sensitivity analysis, data assessment, calibration, and uncertainty analysis of environmental models: PEST and UCODE. These programs are universal in that they can be applied to any computer model; and both have very flexible methods for interacting with application models through ASCII files. Their combination in an Application Programming Interface (API) will yield a full-featured, well-designed, flexible, stable, modular, thoroughly documented foundation for advancing the technology incorporated in UCODE and PEST. Phase 1 of the project is development of the JUPITER API, which will include (1) conventions for program input and output and internal data production and consumption, and (2) subroutines that support commonly used calculations and manipulations, to facilitate use of the API by many researchers in the field. Phase 2 is development of the first applications of the JUPITER API, J_UCODE, J_PEST, and J_MMRI, where J_MMRI is an alternative conceptual model evaluation tool for ranking and weighting models to facilitate multi-model inference. Applications developed using the JUPITER API will provide the opportunity for users to readily: (1) experiment with a number of techniques for generating conceptual models (e.g. geostatistical methods, geologic process modeling, upscaling); (2) compare alternative parameter-estimation algorithms (for example, the algorithms in J_PEST and J_UCODE); (3) "mine" results from various conceptual models for model evaluation, ranking and multi-model inferential analysis, as well as use these results to evolve the conceptual model (e.g. unreasonable parameter-value estimates provide clues to hydrogeologic structure; residual bias provides clues to conceptual model error); and (4) assess data needs to improve the calibration in light of the predictions.

H12G-04 1425h

A Novel Approach to Modeling of Hydrogeologic Systems Using Fuzzy Differential Equations

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The many simultaneously occurring processes in unsaturated-saturated heterogeneous soils and fractured rocks can cause field observations to become imprecise and incomplete. Consequently, the results of predictions using deterministic and stochastic mathematical models are often uncertain, vague or "fuzzy." One of the alternative approaches to modeling hydrogeologic systems is the application of a fuzzy-systems approach, which is already widely used in such fields as engineering, physics, chemistry, and biology. After presenting a hydrogeologic system as a fuzzy system, the author presents a fuzzy form of Darcy's equation. Based on this equation, second-order fuzzy partial differential equations of the elliptic type (analogous to the Laplace equation) and the parabolic type (analogous to the Richards equation) are derived. These equations are then approximated as fuzzy-difference equations and solved using the basic principles of fuzzy arithmetic. The solutions for the fuzzy-difference equations take the form of fuzzy membership functions for each observation point (node). The author gives examples of the solutions of these equations for flow in unsaturated and saturated media and then compares them with those obtained using deterministic and stochastic methods.

H12G-05 1440h

Uncertainty and Sensitivity Analysis for Basic Transport Parameters at the Horonobe Site, Hokkaido, Japan

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Incorporating results from a previously developed finite element model from the Hazama Corporation, an uncertainty and parameter sensitivity analysis was conducted using site-specific data from Horonobe, Japan. Latin Hypercube Sampling (LHS) is used to draw random parameter values from the site-specific measured, or approximated, physicochemical uncertainty distributions. Using pathlengths and groundwater velocities extracted from the currently available three-dimensional, finite element flow and particle tracking model for Horonobe, breakthrough curves for multiple realizations were calculated with the semi-analytical, one-dimensional, multirate transport code, STAMMT–L. A stepwise linear regression analysis using the 5, 50, and 95% breakthrough times as the dependent variables and LHS sampled site physicochemical parameters as the independent variables was used to perform a sensitivity analysis. Results indicate that the distribution coefficients and hydraulic conductivities are the parameters responsible for most of the variation among simulated breakthrough times. This suggests that researchers and data collectors at the Horonobe site should focus on accurately assessing these parameters and quantifying their uncertainty.

H12G-06 1455h

Backward-in-time Modeling to Identify Sources of Reactive Solutes in Groundwater Using Probabilities Conditioned on Concentration Measurements

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When contamination is observed in an aquifer, the source of contamination is often unknown. We present an approach that can be used to identify sources of contamination based on the observed distribution (spatial, temporal, or both) of the contaminant plume. Using backward-in-time advection dispersion theory, we first obtain a backward location probability distribution that describes the possible prior positions of the contamination. This distribution is independent of the measured concentrations of the contaminant. Next, we condition the probability distribution on the measured concentrations, resulting in an improvement in the accuracy and a reduction in the variance of the backward location probability distribution. We illustrate the approach for a reactive solute (first-order decay), and demonstrate its applicability for identifying possible source locations of a trichloroethylene plume at the Massachusetts Military Reservation.

H12G-07 1510h

MAXIMUM LIKELIHOOD BAYESIAN AVERAGING OF SPATIAL VARIABILITY MODELS IN UNSATURATED FRACTURED TUFF

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Hydrologic analyses typically rely on a single conceptual-mathematical model. Yet hydrologic environments are open and complex, rendering them prone to multiple interpretations and mathematical descriptions. Adopting only one of these may lead to statistical bias and underestimation of uncertainty. Bayesian Model Averaging (BMA) [Hoeting et al., 1999] provides an optimal way to combine the predictions of several competing models and to assess their joint predictive uncertainty. However, it tends to be computationally demanding and relies heavily on prior information about model parameters. Neuman [2003] proposed a Maximum Likelihood version (MLBMA) of BMA to render it computationally feasible and to allow dealing with cases where reliable prior information is lacking. We apply MLBMA to seven alternative variogram models of log air permeability data from single-hole pneumatic injection tests in six boreholes at the Apache Leap Research Site (ALRS) in central Arizona. Unbiased ML estimates of variogram and drift parameters are obtained using Adjoint State Maximum Likelihood Cross Validation [Samper and Neuman, 1989a] in conjunction with Universal Kriging and Generalized Least Squares. Standard information criteria provide an ambiguous ranking of the models, which does not justify selecting one of them and discarding all others as is commonly done in practice. Instead, we eliminate some of the models based on their negligibly small posterior probabilities and use the rest to project the measured log permeabilities by kriging onto a rock volume containing the six boreholes. We then average these four projections, and associated kriging variances, using the posterior probability of each model as weight. Next, we cross-validate the results by eliminating from consideration all data from one borehole at a time, repeating the above process, and comparing the predictive capability of MLBMA with that of each individual model. Finally, we use the individual and MLBMA model results to predict pressure variations with time obtained independently through cross-hole pneumatic injection tests at the ALRS. We find that MLBMA is superior to any individual geostatistical model of log permeability among those we consider at the ALRS.

H12G-08 1525h

Transport of Surface-Active Solutes in a Heterogeneous Vadose Zone: Dealing With Limited Data Collection

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Realistic modeling of the non-steady state transport of surface-active compounds through unsaturated heterogeneous soils requires representation of the spatial variability in the relationships of soil moisture retention and the unsaturated hydraulic conductivity. In the case of limited resources for site characterization, the question arises as to what type of data to collect and how to best represent these relationships at locations where data are lacking. This study investigates the impact on surface-active solute transport predictions of the collection: 1) of different types of data, air-water retention curves or saturated hydraulic conductivities, 2) at different locations, and 3) of different ways of describing the spatial variability of the data: similar media scaling, Leverett scaling and a categorical-continuous method based on the pore-size distribution index. Based on a series of geostatistically-conditioned realizations, simulations of groundwater flow and contaminant transport were generated utilizing subsets of the soil property measurements from the Las Cruces trench site and compared to simulations utilizing the entire set of soil property measurements from that site. Since preliminary simulations showed that the results were influenced by the flux rate at the land surface, the degree of uncertainty under different infiltration rates was also assessed.

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H12H MCC: 3020 Monday 1340h

Hydrogeophysics: Characterization and Monitoring of Soil Properties and Processes in the Laboratory I *(joint with NG, MR)*

Presiding: **L Slater,** Rutgers University**; E Atekwana,** University of Missouri-Rolla

H12H-01 1340h

Effect of Hydrocarbon Biodegradation on the Low-Frequency Electrical Properties of Unconsolidated Sediments

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A laboratory sand column experiment was conducted to investigate the effect of biodegradation of diesel on low-frequency electrical measurements over a period of 36 weeks. Uniform fine to medium grained sands were used in the columns with the following experimental treatments: nutrients; nutrients + diesel; nutrients + diesel + bacteria. The first two columns were kept sterile by adding 200 mg/l mercury chloride, whereas the third column was kept active. Spectral electrical measurements were conducted in the frequency range 0.1 to 1000 Hz biweekly for the first twenty weeks and monthly for the duration of the experiment. Evidence of biodegradation in the active column was determined by monitoring the changes in concentration of terminal electron acceptors (e.g., nitrate and sulfate) and total benzene, toluene, ethylbenzene and xylene (BTEX). After 36 weeks, we observed in general that the active column exhibited major changes in electrical and geochemical parameters compared to sterile columns. The active column showed about 100 and 120 percent increase in the magnitude of the real and imaginary conductivities, respectively. No significant increases in the real and imaginary conductivity were observed in the sterile columns. We note that, (a) the relative increase in the real conductivity exceeded the relative increase in the fluid conductivity, and (b) the relative increase in the imaginary conductivity (polarization) exceeded the relative increase in the real conductivity. The active column further showed 70 to 90 percent depletion in nitrate, sulfate and BTEX concentrations. Moreover, magnesium and calcium concentrations increased within the active column to about 120 to160 percent (respectively) compared to the sterile column. The major biogeochemical changes associated with the active column are an indication of active microbial degradation of diesel. Moreover, the increase in calcium and magnesium ion concentrations in the active column, concurrent with a decrease in pH is indicative of mineral weathering accompanying the degradation process. Based on the geochemical analyses and the electrical parameters, we argue that microbial alteration of surface chemistry (increase of surface charge density and ionic mobility) at the mineral-fluid interface, coupled with increases in the electrical conductivity of the electrolyte, explain our observations in the active column. We conclude from this study that low-frequency electrical measurements have the potential to monitor the biogeochemical and physical changes of hydrocarbon contaminated soils undergoing biodegradation.

H12H-02 1355h

Geoelectrical Evidence of Microbial Degradation of Diesel Contaminated Sediments

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The alteration of physical properties by microbial activity in petroleum contaminated sediments was investigated using geophysical techniques in laboratory column experiments. Microbial population growth was determined by the Most Probable Number technique (MPN), community dynamics were determined by the rDNA intergenic spacer analysis (RISA), microbial mineralization of diesel fuel was assessed using dissolved inorganic carbon (DIC), enhanced mineral dissolution was determined by dissolved calcium, and the vertical geoelectrical profile was measured using DC resistivity (converted to conductivity). The columns simulated a saturation profile and contained sanitized, uniform sand with the following experimental treatments: diesel + microbes, diesel, microbes, and no treatment. After 16 months, two important conclusions were drawn. First, the relative increase in magnitude of the parameters measured was highest in the diesel + microbe column (showing at least 110% increase), lower in the diesel column and lowest (actually showing a decrease) in the column with no treatment. Further, the diesel + microbe column showed the greatest increase in oil degrading microbial populations (135%) compared to the column with no treatment, which showed no changes. Secondly, the depth at which the conductivity reached the maximum occurred within and slightly above the diesel layer (which represents a depth that was originally water wet). It was further observed that the relative change in bulk conductivity below the saturated zone is of a lower magnitude than above (<10%). These results suggest the diesel layer, and the zone slightly above, were the most biologically active. Additionally, the diesel + microbe column showed RISA fragments attributed to microbial succession typically observed in organic contaminant plumes. A simple Archie's Law analysis was used to estimate the pore water conductivities necessary to reproduce the bulk conductivity measured. This analysis shows that relative to the column with only microbes (selected as the control to be most representative of field conditions), the diesel column revealed a 2.3 fold increase and the diesel + microbe column showed a 3 fold increase in pore water conductivity. This increase was located within the diesel layer above the water saturated zone. Within the saturated zone, the no treatment column showed a 0.81 fold increase, the diesel column a 1.28, and the diesel + microbe column 1.45. We conclude from this study that microbial activity and the resultant biogeochemical changes played an important role in modifying the geoelectrical properties of aquifers and sediments rich in organic carbon and mineralized by bacteria by increasing the bulk conductivity. This conductive zone occurred within and immediately above the free-phase petroleum layer. In natural environments with high concentrations of organic compounds available as electron donors, geophysical techniques may potentially be used as indicators of microbial activity. Notice: This is an abstract of a proposed presentation and does not necessarily reflect the United States Environmental Protection Agency (EPA) policy. The actual presentation has not been peer reviewed by EPA. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

H12H-03 1410h INVITED

Investigating the Geoelectrical Stratigraphy of Clean and Contaminated Unconfined Aquifers

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Various electrical and electromagnetic techniques are being used to image the geoelectrical statigraphy of unconfined aquifers and infer the spatial distribution of water content and immiscible contaminant concentration. This inference is dependent on the accuracy of the petrophysical relationships between the geoelectrical properties (i.e., electrical conductivity and dielectric permittivity) and pore fluid contents. Currently, Archie's Law and Topp's Equation are two commonly used petrophysical relationships for geoelectrical data analysis. These two relationships were used to infer the vertical water content profile from geoelectrical data collected in a large test cell (3 meter diameter, 1.7 meters depth) containing repacked Borden sand. This profile differs from the water content profile predicted from the van Genuchten equation and obtained from neutron moisture probe measurements; the van Genuchten model and neutron data give mutually consistent results. Potential causes for this discrepancy and their impact on the estimation of water content and immiscible contaminant concentration are examined.

H12H-04 1425h INVITED

Geoelectrical Methods Applied to Contaminant Plumes. From Laboratory to Field Investigations

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At present, the self-potential method, a relatively cheap field method, is rarely used in environmental investigations due to the lack of reliable interpretation schemes and poor knowledge of the signal-to-noise ratio. The self-potential signals measured at the ground surface with a new generation of non-polarisable electrodes represent the ground signature of in situ polarization mechanisms. Two main driving mechanisms have been evidenced. The first is the electrokinetic response associated with ground water flow. The second contribution is associated with redox conditions in the ground. In this talk, we will present a set of new data for these two mechanisms. These data include core measurements, measurements in plexiglas tanks filled with porous sands, and finally a field experiment. The field investigation is related to the detection of a contaminant plume through a combination of electrical resistivity tomographies and self-potential investigations. We show how laboratory experiments are helpful to determine redox conditions in the contaminant plume and we will discuss the principle of electro-redox geobatteries including the role of biofilm of bacteria.

H12H-05 1440h

Electrical Spectroscopy of Permo-Triassic Sandstone From the United Kingdom

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Electrical spectroscopy measurements in the range of mHz to kHz have been made on the dominantly red Permo-Triassic sandstone from the United Kingdom. Samples have been selected from borehole cores from all of the main outcrop areas of sandstone and represent a wide variety of lithologies. This sandstone is an important aquifer for several major cities including Manchester and Birmingham. The samples have been fully saturated with sodium chloride brines and a synthetic groundwater solution that is higher in calcium and magnesium ions than sodium and which closely matches the cation concentrations of the groundwater at Birmingham. Electrical measurements were made using a four-electrode arrangement of silver-silver chloride electrodes. Most of the electrical spectra show a clear, slightly asymmetric, electrical relaxation phenomenon with relaxation peaks in the range of 0.001 Hz to 20 Hz. These relaxation phenomena can be fitted very well by a generalised Cole-Cole model. The relaxation time from this model is found to correlate closely with the dominant pore-throat size from mercury injection. Normalising the chargeability, Cole-Cole m parameter, by the conductivity gives a polarisation magnitude which correlates well with the pore surface to volume ratio (S_{POR}) for sandstone samples with an even distribution of surface coating clays. The information obtained from the electrical spectra is very useful. The pore-throat size is important in controlling the permeability and in particular the flow of non-aqueous phase fluids. The pore surface area has links to the sorbtion properties of the rock, which are important in estimating contaminant transport. The electrical spectra also provide a useful fingerprint of individual lithologies which could be used for correlation between boreholes or outcrops.

H12H-06 1455h

Low-Frequency Electrical Properties of Zero Vvalent Iron-Sand Columns: Implications for Monitoring the Performance of Reactive Iron Wall Barriers

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The reactive iron barrier is an in-situ technology for passive remediation of chlorinated solvents and heavy metals. Redox reactions occurring on the iron surface effectively remove these contaminants from groundwater. The effectiveness of this redox reaction diminishes with time due to oxidation and precipitation occurring on the metal surface, such that the long-term performance of reactive barriers is uncertain. Non-invasive measurement methods for evaluating reactive barrier performance are thus required to support remedial strategies at reactive barrier installations. Low-frequency (0.1-1000 Hz) electrical measurements are sensitive to the electrochemistry of the metal surface-pore fluid interface. We are conducting a series of laboratory experiments to assess the sensitivity of electrical methods (induced polarization and resistivity) to changes in the physicochemical properties of the metal-fluid interface that occur over time. In this paper we present the results of baseline studies on zero-valent iron-sand columns as a function of (a) reactive iron concentration (b) saturating fluid chemistry, and (c) degree of surface oxidation. The sensitivity of low-frequency electrical parameters to total zero-valent iron (Fe0) surface area was investigated by synthesizing Fe-Ottawa sand samples with varying Fe0 concentration from 0-10 percent. The dependence on ionic strength and electrolyte activity was investigated by making measurements on samples saturated with 0.001-1.0 for NaNO3, NaCl and CaCl2 solutions. The effect of pH was evaluated at constant electrolyte activity. As a first step towards evaluating the sensi-

tivity of electrical measurements to reduction in reactive iron performance, measurements were made over a three month period of ageing and correlated with geochemical indicators (pH, Eh, electrical conductivity, iron concentrations) of Fe surface oxidation and precipitation. We find that induced polarization (IP) parameters are highly sensitive to Fe0 surface area whereas conduction parameters measured with the resistivity method are insensitive to Fe0 concentration over the investigated range. Polarization at the iron-electrolyte interface shows a power law relationship with electrolyte activity for all solutions and is consistent with Warburg impedance theory. Power-law exponents are slightly higher than that predicted for the active ion species based on Warburg impedance theory. Polarization magnitude depends on ionic composition of the electrolyte with the magnitude following the order CaCl2: NaCl: NaNO3. Conduction parameters are insensitive to ionic composition at constant electrolyte activity. Electrolyte activity exerts a strong control on the polarization relaxation length-scale, with time constant of the relaxation decreasing with increasing electrolyte activity. Polarization parameters measured during three months of ageing are clearly correlated with time and suggest that electrical measurements are sensitive to reduction in reactive iron performance.

H12H-07 1510h INVITED

Resolving the Impact of Biological Processes on DNAPL Transport in Unsaturated Porous Media Through Nuclear Magnetic Resonance Relaxation Time Measurements

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This research leads to a better understanding of how physical and biological properties of porous media influence water and dense non-aqueous phase liquid (DNAPL) distributions under saturated and unsaturated conditions. Knowing how environmental properties affect DNAPL solvent flow in the subsurface is essential for developing models of flow and transport needed for designing remediation and long-term stewardship strategies. We investigate the capability and limitations of low-field nuclear magnetic resonance (NMR) relaxation decay-rate measurements for determining environmental properties affecting DNAPL solvent flow in the subsurface. For in-situ subsurface environmental applications, low-field proton NMR measurements are preferred to conventional high-field techniques commonly used to obtain chemical shift data, because low field measurements are much less degraded by magnetic susceptibility variations between rock grains and pore fluids that significantly interfere with high-field NMR measurements. The research scope includes discriminating DNAPLs in water-wet or solvent-wet environments and the impact of biological processes on their transport mechanisms in porous media. Knowledge of the in situ flow properties and pore distributions of organic contaminants are critical to understanding where and when these fluids will enter subsurface aquifers. Experiments determined that commonly found subsurface DNAPLs containing hydrogen, such as trichloroethylene and dichloroethylene, are detectable and distinguished from water in soils. Related experiments concern the effects of bacterial accumulation in saturated and unsaturated porous media on water and DNAPL pore-size distributions. These include synthetic bio-film matrix as a surrogate bio-film and sand, biological agents to grow biofilms, and multiple pore sizes to determine if bio-films prefer certain pore-size ranges. NMR microscopy focused on imaging a single biofilm in a 1 mm capillary reactor. This system serves as a model for a single large anisotropic pore of a porous media and allows for determination of T2, spin-spin magnetic relaxation behavior within the biofilm. Measurement and analysis protocols along with packing and saturating protocols are evaluated. The anticipated outcome of this research will establish the utility of proton NMR laboratory and field measurements for elucidating flow properties in different porous media, detecting microbiological influence on DNAPLs, and DNAPL pore-fluid partitions under saturated and unsaturated conditions.

H12H-08 1525h

Clay in Contact Zones: NMR and Ultrasonic Effects

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Presence of clay minerals in soils can affect acoustic impedance considerably. Clay in the contact area lowers the micro- and macrostructural impedance of the formations. We have investigated changes in acoustic properties as the clay dries and changes from a damping to a cementing agent. The study is aimed at understanding the role of clay minerals in saturated to partially saturated soils. METHODS: Acoustic waves were propagated through two discs in contact. The contact zone between the discs was filled with thin layers of dry clay, clay slurry that was allowed to dry slowly, and air. We monitored water content by weighing. Pore size distribution was measured by NMR experiments. We report here waveforms of P- and S-wave signals transmitted through the air-coupled, dry clay-coupled, and cemented clay-coupled quartz discs. RESULTS: We find that the state of the clay changes the wave propagation characteristics in a very pronounced manner. Addition of a water saturated clay layer to quartz discs dampens waves significantly. Significant signal damping occurs after applying a 0.05 mm thick clay layer in the contact region between glass discs. The effect is more pronounced in the S-waves than in the P-waves. However, as the clay dries, it acts as a strong cementing agent and enhances wave propagation through the clay-cemented quartz discs. The NMR experiments allowed us to measure the pore size distributions corresponding to the acoustic measurements. As the average water content decreases, the average water layer thickness decreases from 600 nm in the wet slurry to 56 nm in the partially saturated clay, and 7 nm in the almost dry clay cement with most of the signal coming from capillary water.

URL: http://pangea.stanford.edu/~manika/AGU2003

H12I MCC: 3022 Monday 1600h

Designing a Network of Hydrologic Observatories *(joint with A, B)*

Presiding: **R P Hooper,** Consortium for the Advancement of Hydrologic Sciences, Inc. (CUAHSI)**; K Reckhow,** North Carolina State University

H12I-01 1600h INVITED

A University Consortium for the Advancement of Hydrologic Research

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Seventy-six research universities across the United States have joined to form the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI), a non-profit corporation. With support from the National Science Foundation, CUAHSI has embarked upon the design and development of programs to enable hydrologic research at larger spatial scales over longer time periods than has been within the grasp of individual investigators. The guiding principle of this design has been an embracing of the entire hydrologic cycle to enable research at the interfaces among traditional hydrologic subdisciplines and between hydrologic science and allied disciplines in the earth and life sciences. To improve our predictive understanding of hydrologic phenomena, the fundamental approach that has been adopted is the development of multidisciplinary, coherent data sets to enable testing of hypotheses in different hydrologic settings across a range of spatial and temporal scales. Four mutually supportive program elements have been conceived: a network of hydrologic observatories (the subject of this special session) designed strategically to collect additional data at large scales (on the order of 10,000 km2) and to leverage existing investments in small-scale intensive studies and in larger scale monitoring activities; hydrologic information systems to develop a comprehensive data model for integrating disparate data types, to develop the cyberinfrastructure necessary for systematic data collection and dissemination and to support community models; hydrologic measurement technology facility to broker instrumentation services from existing sources, to provide cutting edge tools along with the necessary support to use them, and to develop new hydrologic instrumentation needed to advance the science; and hydrologic synthesis center to provide a venue for hydrologic sciences from a range of disciplines to work on topics ranging from inter-observatory comparison to evolving CUAHSI's science agenda. Each of these elements has a dual role. They contribute towards the development and dissemination of the multidisciplinary data set to be collected at observatories that lies at the heart of CUAHSI activities. However, they also serve individual scientists to advance their own research by providing, respectively, access to data, a generic data model and modeling tool box, access to instrumentation at low or no cost, and access to a venue to pursue collaborative research. In this manner, CUAHSI strives to advance both its stated research agenda and to support research of individuals.

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Hydrologic Observatories: Design, Operation, and the Neuse Basin Prototype

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Hydrologic observatories are conceived as major research facilities that will be available to the full hydrologic community, to facilitate comprehensive, cross-disciplinary and multi-scale measurements necessary to address the current and next generation of critical science and management issues. A network of hydrologic observatories is proposed that both develop national comparable, multidisciplinary data sets and provide study areas to allow scientists, through their own creativity, to make scientific breakthroughs that would be impossible without the proposed observatories. The core objective of an observatory is to improve predictive understanding of the flow paths, fluxes, and residence times of water, sediment and nutrients (the "core data") across a range of spatial and temporal scales across interfaces'. To assess attainment of this objective, a benchmark will be established in the first year, and evaluated periodically. The benchmark should provide an estimate of prediction uncertainty at points in the stream across scale; the general principle is that predictive understanding must be demonstrated internal to the catchment as well as its outlet. The core data will be needed for practically any hydrologic study, yet absence of these data has been a barrier to larger scale studies in the past. However, advancement of hydrologic science facilitated by the network of hydrologic observatories is expected to focus on a set of science drivers, drawn from the major scientific questions posed by the set of NRC reports and refined into CUAHSI themes. These hypotheses will be tested at all observatories and will be used in the design to ensure the sufficiency of the data set. To make the observatories a national (and international) resource, a key aspect of the operation is the support of remote PI's. This support will include a resident staff of scientists and technicians on the order of 10 FTE's, availability of dormitory, laboratory, workshop space for all scientists, and the awarding of travel support out of observatory funds. The conflicting goals of support for a PI-designed observatory and a network of community-available observatories will be achieved by allocation of resources to assure both goals will be met. It is proposed that these resources be divided into three pools: • Core data pool. Data to be collected by the observatory PI's and staff, and where possible, augmented by existing (e.g., USGS) data collection. • Design pool. Available to support the designs of observatory PI's. • Community pool. Available to non-PI scientists to test cross-observatory hypotheses. Application of these design and operation concepts to the design of the Neuse basin prototype hydrologic observatory is briefly discussed.

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