more improvement in estimating more realistic runoff amount.

H51A-0776 0830h POSTER

Biogeochemical Tracers in Arctic Rivers: Linking the Pan-Arctic Watershed to the Arctic Ocean (the PARTNERS project)

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The Arctic is undergoing unusual and apparently progressive changes in the land, ocean, and atmospheric components of the hydrologic cycle that could have long-term consequences for both local and global climate. Understanding sources and fates of river discharge is important because rivers make an enormous contribution to the freshwater budget of the Arctic Ocean, presently accounting for 50 to 60 percent of all freshwater inputs. The overall objective of the PARTNERS project is to use river water chemistry as a means to study the origins and fates of continental runoff. Through a collaboration among Russian, Canadian, Germany, and U.S. scientists, we have compiled and evaluated existing biogeochemical data sets for large arctic rivers. Our synthesis of nutrient and sediment data sets has revealed large gaps and uncertainties in biogeochemical fluxes, so in the next phase of the project we will be collecting and analyzing new samples from the six largest arctic rivers (Yenisey, Lena, Ob', Mackenzie, Yukon, Kolyma). Samples will be analyzed for a wide range of constituents, focusing on compounds that can be used as tracers of river water in the Arctic Ocean or that give clues about watershed sources or processes. Sampling will occur several times per year for four years (2003-2007). This multinational, multidisciplinary project will greatly improve our understanding of land-ocean linkage in the pan-Arctic watershed.

H51A-0777 0830h POSTER

Atmospheric processes responsible for the interannual seesaw-like summer dry and wet regimes in Northern Eurasia

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In northern Eurasia, interannual variability of summer (June–August) precipitation has a marked signature with east-west seesaw-like interchange of dry and wet extremes across Siberia. For example, an out-of-phase relationship with nearly 6–8-year cycle in the basin-scale precipitation for the Ob and Lena River and associated replacement of Siberian wet and dry regimes appear from 1970s through 1980s. (Fukutomi et al. 2002, submitted to JHM). We further investigate the atmospheric conditions for these regimes based on the NCEP reanalysis and precipitation products (PLEC/L).

A singular value decomposition (SVD) analysis is applied to 500hPa Northern Hemisphere geopotential height and the Siberian precipitation for 30 summers 1972-2001. The leading mode of coupled variability (SVD1) is characterized by an east-west dipole structure of Eurasian quasi-stationary wave and precipitation anomalies. When eastern Siberia is wet, a low-height anomalies accompanied by lower-troposheric cold-air anomalies are formed, while a high-height anomalies with warm-air anomalies are produced over western Siberia; the reverse situation is established at eastern Siberian dry case. Three sets of eastern Siberian wet (dry)–western Siberian dry (wet) extremes are selected to examine the physical processes in detail.

The seasonal variances of daily 2–6-day (synoptic scale) filtered sea level pressure fields are enhanced in the wet and low-height anomalies while reduced in the dry and high-height anomalies at each extreme phase, which indicates that remarkable interannual changes in the location of genesis and tracks of synoptic-scale disturbances occur in association with these specific regimes. The analysis with eddy statistics demonstrates an impact of synoptic-scale eddy activities on the maintenance of the Eurasian quasi-stationary wave structure at the extreme phases of dipole rainfall anomalies. An eddy vorticity flux convergence (divergence) is concentrated in the low- (high-) height anomalies in the upper troposphere, and eddy heat flux convergence (divergence) is also superimposed on the low- (high-) height anomalies in the lower troposphere. These features suggest that the barotropic feedback induced by synoptic-scale eddies acts to reinforce the Eurasian quasi-stationary waves, and the baroclinic feedback acts to dissipate the thermal structure of these wave anomalies.

H51A-0778 0830h POSTER

Dynamic Observations of Ground Water Flow Through Discontinuous Permafrost Zones and Varied Alluvial Media

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The site-specific ground water regime affiliated with a permafrost environment has not yet received investigative emphasis commensurate to its level of importance. We are studying this hydrological regime in Fairbanks AK through a series of integrated studies that characterize ground water flow by deploying a series of ground water flow systems to continuously monitor flow rates and directions within the suprapermafrost aquifer, taliks, thaw channels, subpermafrost aquifer and areas proximal to the nearby Chena River. Ground water hydrology in a permafrost environment is complicated not only by water flowing through varied surficial materials, but also by factors unique to the permafrost environment. Changes in ground ice and the active layer can alter the water budget in a manner which is hard to quantify, as it adds and removes water according to short-term seasonal and long-term climatic temperature variations. These conditions may impose temporal changes on ground water flow as it moves along already complex pathways constrained by the irregularly shaped impermeable masses of permafrost. We observed variations in flow rates and directions coincident with what would be expected based on local permafrost configuration. Melting snow pack and river ice can both serve as sources of aquifer recharge, although the magnitude of that recharge can vary spatially depending on available recharge and infiltration potential. Areal recharge can displace portions of the ground water reservoir through the river banks, manifested as ground water reversals in wells proximal to the river. Conversely, melting river ice during spring break-up imposed ground water reversals where pulses of river water were emitted to the ground water aquifer. These observations of local ground water flow rates and directions, contribute to a holistic understanding of ground water flow in permafrost environments, especially when taken in the larger context of other related geophysical and modeling studies aimed to understand permafrost.

H51B MCC: Hall C Friday 0830h

Surface Water Hydrology and Water Resources Posters

Presiding: **J Jacob,** University of Florida

H51B-0779 0830h POSTER

Operating Water Resources Systems Under Climate Change Scenarios

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Population and industrial growth has resulted in intense demands on the quantity and quality of water resources worldwide. Moreover, climate change/variability is making a growing percentage of the earth's population vulnerable to extreme weather events (drought and flood). The 1996 Saguenay flood, 1997 Red River flood, the 1998 ice storm, and recent droughts in prairies are few examples of extreme weather events in Canada. Rising economic prosperity, growth in urban population, aging infrastructure, and a changing climate are increasing the vulnerability of Canadians to even more serious impacts. This growing threat can seriously undermine the social and economic viability of the country. Our ability to understand the impacts of climate change/variability on water quantity, quality, and its distribution in time and space can prepare us for sustainable management of this precious resource. The sustainability of water resources, over the medium to long-term, is critically dependent on the ability to manage (plan and operate) water resource systems under a more variable and perhaps warmer future climate.

Studying the impacts of climate change/variability on water resources is complex and challenging. It is further complicated by the fact that impacts vary with time and are different at different locations. This study deals with the impacts of climate change/variability on water resources in a portion of the Red River Basin in Canada, both in terms of change in quantity and spatial-temporal distribution.

A System Dynamics model is developed to describe the operation of the Shellmouth Reservoir located on the Red River in Canada. The climate data from Canadian Global Coupled Model, CGCM1 is used. The spatial system dynamics approach, based on distributed parameter control theory, is used to model the impacts of climate change/variability on water resources in time and space. A decision support system is developed to help reservoir operators and decision makers in sustainable management of water resources. The decision support system helps in analyzing the impacts of different reservoir operation scenarios, under changing climate conditions, by exploring multiple- what-if- scenarios. Canadian study areas and data sets are used for the research. However, the proposed approach provides a general framework that can be used in other parts of the world.

H51B-0780 0830h POSTER

The Impact of a Flood Retarding Structure on Watershed Runoff Under Dry, Average, and Wet Climatic States

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Flood damage to agricultural lands during the late 1930s and early 1940s prompted passage of the Federal Flood Control Act of 1944 (P.L. 78-534) and the Watershed Protection and Flood Prevention Act (P.L. 83-566) of 1953. As a result of these flood abatement programs, the USDA SCS constructed about 2,500 flood retarding structures (FRSs) in the State of Oklahoma to control runoff from about 22,000 km2. One of the pilot projects implemented in the flood abatement programs was the treatment of tributaries in the Washita River Basin in southwestern Oklahoma. The Little Washita River Experimental Watershed (LWREW) represents one such tributary that was instrumented during the 1960s to determine the downstream hydrologic impacts of the SCS flood retarding structures. Previous studies have investigated the impacts of FRSs on water yield, peak reduction, and flow frequency for tributaries in the Washita River Basin. Implicit in these investigations was the assumption that changes in measured runoff characteristics before and after construction of the FRSs were due only to the construction of these structures. Even though decade-long climate variations during the 1961-1990 period were recognized, they were not explicitly considered in previous analyses and resulted in difficult interpretation of results. Furthermore, flood frequency studies were limited by the short period of record before and after the installation of the FRSs. Computer simulation of watershed response provides the opportunity to determine the impacts of FRSs on runoff characteristics without the confusing effect of climate variations. The objective of this study is to determine the effect of a FRS on the flow regime and peak flows of subwatershed 442 within the Little Washita River Experimental Watershed in southwestern Oklahoma. Observed precipitation and streamflow data are complemented by computer simulations to overcome many of the shortcomings in previous analyses. Climate generation techniques are employed to assess of the magnitude of the impacts of the FRS relative to changes in watershed response due to decade-long climate variations. The results of this study provide a better estimation of the beneficial impacts of FRSs on downstream flow regime and the reduction of downstream flood risk under dry, average, and wet climatic conditions.

H51B-0781 0830h POSTER

Water Level Fluctuations in the Plata Basin (South America) From Topex/Poseidon Satellite Altimetry

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Time series of water level along two major rivers of the Plata basin in South America (Parana and Paraguay) are examined using altimetry data from the Topex/Poseidon satellite over a 9-year period (1993-2001). The methodology for detecting water surfaces over continents in the radar echoes is described. Water level time series at 14 sites corresponding to intersections of the satellite tracks with the rivers, and at 7 sites corresponding to flooded areas, are constructed. The amplitude of the seasonal cycle at each site decreases with increasing latitude. The time series for the Lower Parana, Paraguay and Upper Parana differ mainly by a time-lag which suggests that perturbations in water level propagate along the rivers with a mean speed of about 0.1 ms-1. The time series at locations on the Parana near its confluence with the Paraguay differ significantly from those at locations further upstream.

The interannual variability of the Lower Parana, with a strong peak in early 1998 and minima in early 1996 and 2000, is closely related to the impacts of El Nio/Southern Oscillation. The Upper Parana and Paraguay show similar features with smaller amplitudes. The substantial variability of these rivers before 1995, on the other hand, cannot be straight forwardly attributed to ENSO effects. A likely reason is the variability of the South American monsoon that affects the northern part of the Plata basin. It is concluded that satellite altimetry has great promise as a technique for dense and continuous monitoring of river water levels, and thereby of regional climate variability in the basins of large rivers.

H51B-0782 0830h POSTER

Stream Flow Prediction using Spatially Distributed Travel Time Method Utilizing Remote Sensing and GIS

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The availability of spatial information from remote sensing and the ability of Geographic Information Systems (GIS) to handle such data efficiently has contributed much to charactering the topography and land cover characteristics required to understand the runoff response of watersheds. Remote sensing provides valuable data to watershed modeling including vegetation cover, percent imperviousness and also runoff curve number and roughness coefficients are derived from land cover data. In this research, spatially distributed runoff was estimated for the Simms creek in the St. Johns River Water Management District (SJRWMD), Florida using the United States Department of Agriculture, Natural Resources Conservation Service-Curve Number (USDA-NRCS-CN) method. Land use data from Digital Orthophoto Quarter Quadrangles (DOQQ) and Landsat Enhanced Thematic Mapper Plus (ETM+) for 1990, 1995 and 2000 were used to estimate spatially distributed curve numbers. A DEM-GIS based runoff routing technique, based on a 1-D kinematic wave flow assumption was developed to generate hydrographs based on travel time to the watershed outlet using spatially distributed data. Comparison was made between the observed and predicted runoff hydrographs and three existing models: the Time-Area method, the Snyder unit hydrograph model and TOPMODEL using, 17 storm events from 1990, 1995, 1999 and 2000. Results indicate that the distributed travel time method can accurately predict runoff response for large isolated storms with an average prediction efficiency of 0.57. The travel time approach performed better than the Snyder method and TOPMODEL, which had prediction efficiencies of 0.31 and V0.24 respectively. The Time-Area method performed slightly better than the distributed travel time method with an average efficiency of 0.66.

(KEY TERMS: runoff, curve number, travel time, DEM, GIS, remote sensing)

H51B-0783 0830h POSTER

Topology and Parameters of Watershed and River Networks

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Due to the inherent spatial complexity of large hydrologic systems, for modeling purposes, rather than applying lumped models to represent entire basins, it is better to subdivide them into elementary flow elements organized as networks by virtue of their topologic relations. Likewise, each element should have different hydrologic properties to account for the terrain spatial variability, and different hydrologic behavior to account for the different flow processes. Topology is the relation of the flow elements of a system to one another, so that each of them "knows" which other elements are upstream and which are downstream. Establishing the topology is fundamental for flow routing, as well as for tracking constituent particles transported by water. The geographic information systems (GIS) tools developed in this study satisfy the same needs previous work with raster data did, but these new tools apply to vector data (i.e., watershed polygons and stream lines). Use of vector data, as oppose to raster data, has the advantage that each element represents a real-world flow element and, consequently, sets a better ground for physically-based modeling, not to mention that overall it is more accurate and better suited for modeling large study areas. In this study, methods and GIS tools to describe the hydrologic topology of a system in the vector environment have been developed. The study focuses on the algorithms developed for determination of the topology and on their application. Similar to the raster-based functions FLOWDIRECTION, FLOWACCUMULATION, FLOWLENGTH and WATERSHED included in commercially available GIS software packages, a set of vector-based tools for flow network navigation, drainage area estimation, flow length calculation and drainage divide determination are proposed. The data required by these tools are a stream network and corresponding incremental drainage areas in vector format (i.e., lines and polygons).

H51B-0784 0830h POSTER

An intercomparison of the kinematic wave and Boussinesq approximations for variable geometry hillslope-storage models of subsurface flow

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Kinematic wave and Boussinesq models are commonly used to simulate subsurface flow in sloping aquifers due to their simplicity and amenability to analytical solutions compared to more complex numerical models based on Richards' equation. Unfortunately these simple models are also limited to idealized hillslope configurations in terms of geometry, parameters, and boundary conditions. Recently a "hillslope-storage" formulation has been developed for both the kinematic wave and Boussinesq equations whereby the three-dimensional soil mantle is mapped into a one-dimensional storage capacity function. Plan shape is accomodated by the hillslope width function in both models, whereas profile shape is incorporated in the kinematic wave model via the bedrock curvature function. The ability to account for plan and profile characteristics in these new hillslope-storage kinematic and Boussinesq equations allows us to model important topographic controls on subsurface flow dynamics and surface runoff generation. In this paper the hillslope-storage Boussinesq model is extended to handle profile curvature by introducing a locally variable bedrock slope angle. The behavior of the two models is then compared by computing the storage profiles and outflow hydrographs for a set of nine representative hillslope types under free-drainage and recharge conditions for both gentle and steep hillslopes. These nine hillslope types are obtained by combining three plan curvatures (convergent, uniform, divergent) and three profile curvatures (concave, straight, convex). A dimensional analysis is carried out to characterize the observed storage and outflow response functions over a broader range of hillslope types.

H51B-0785 0830h POSTER

Significance of microtopography as a control on surface-water flow in the Everglades

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Microtopographic variation of 30-cm or more often is present in wetlands, influencing water budgets by affecting the cross sectional area available for surface flow. Surface-water exchange with sediment is also affected if water levels decline enough to expose microtopographic high points. Microtopographic variation also plays a role, along with vegetation, in increasing the resistance to surface flow through wetlands. Relatively few field studies and modeling efforts have attempted to quantify explicitly how microtopography influences surface flow in wetlands. Our study evaluated the role of microtopography on surface-water flow modeled along a 10-km transect in Water Conservation Area 2A in the north-central Everglades. While previous models of surface flow through wetlands advanced by Hammer and Kadlec (1986) and Kadlec (1990) consider the role of microtopography along with vegetation stem density, the applications to field sites do not take full advantage of detailed microtopographic measurements to partition the microtopographic effects. Our model equations followed previous derivations, but were extended in several aspects to account for independent effects of microtopography on (1) characteristic depth controlling cross-sectional area of surface flow, (2) storage exchange with porewater of unsaturated sediment, and (3) stage-dependent flow resistance. Whereas the addition of the characteristic depth formulation and storage-exchange term accounted for only modest improvements in fitting to the data, the addition of stage-dependent flow resistance specified by the measured microtopographic distribution improved model results (RMSE) by 40% over the baseline model simulation that did not consider microtopography independently. Our conclusion is that the effect of microtopography on flow resistance can be very significant to understanding the controls on surface-water flow at wetlands, especially when the surface water declines to depths that begin to expose microtopographic highs.

H51B-0786 0830h POSTER

Use of a Distributed, Finite-Volume, Hydrologic Model to Assess the Sensitivity of the Everglades to De-compartmentalization

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The Everglades, the only remaining subtropical wilderness in the continental USA, is the home to a number of threatened and endangered species. Although the pre-drainage Everglades covered an area of approximately 11,048 km^2, urbanization and farming have reduced its area by approximately 50%. The remaining Everglades has also changed as a result of drainage and compartmentalization by over 2,200 km of levees and canals. This area is also adversely affected by exotic species, nutrient enrichment, contaminants and altered freshwater flows. The $8 billion Comprehensive Everglades Restoration Plan provides a "framework and guide to restore, protect, and preserve the water resources of central and southern Florida, including the Everglades." The success of this project, one of the largest eco-system restoration projects in the world, depends heavily on our understanding of the quantity, quality, timing and distribution of South Florida's predrainage freshwater flow. Consequently, accurate hydrologic modeling is crucial for the restoration of the greater Everglades ecosystem.

The Regional Simulation Model (RSM) developed by the South Florida Water Management District is currently being used to investigate the effect of decompartmentalization on freshwater flow dynamics in parts of the remaining Everglades which includes the Everglades National Park and the Big Cypress National Preserve. The RSM is an implicit, finite-volume, continuous, distributed, integrated surface/ground-water model, capable of simulating one-dimensional canal flow and two-dimensional overland flow in arbitrarily shaped areas using a variable triangular mesh. It has physically-based formulations for the simulation of overland and groundwater flow, evapo-transpiration, infiltration, levee seepage, and canal and structure flows. It is capable of simulating features that are unique to South Florida such as low-relief topography, high water tables, saturation-excess runoff, depth-dependent roughness values and very permeable soils. Since, one of the primary objectives of applying the RSM to the southern Everglades area is to investigate the impact of compartmentalization on stage and flow, the accurate simulation of flow-barriers within the model-domain is crucial for the success of this project. To this end, a 52,817-element mesh is constructed to conform to all major levees, highways and canals within the model domain and to simulate flow across all major bridges and culverts. The resulting numerical model

uses a mesh with an average element-size of 1.81 km^2, and a one-day time-step. It uses recently updated land-use, elevation and soil data for the derivation of static model parameters. The RSM is calibrated using historical time-series data from 1988 to 1995. This paper will highlight the preliminary findings of the sensitivity of the Regional Simulation Model's hydrologic response to de-compartmentalization.

H51B-0787 0830h POSTER

Neural Network Prediction of Ephemeral Streamflow Using Bed-Sediment Thermographs

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Bed-sediment thermographs have been used as an alternative to stream gages for high spatial resolution monitoring of the occurrence and duration of flow in ephemeral streams. Previous investigations using thermal methods have shown mixed results. One of the primary complicating factors is the effect on traditional thermograph analyses of changes in the depth of temperature sensors caused by scouring of the bed sediments. This investigation tested an artificial neural network (ANN) to infer ephemeral streamflow occurrence and duration from thermographs. The ANN parses out meaningful signal characteristics on the basis of attributes of the temperature time series within a moving window of the thermograph. The ANN was trained to identify advective heat flow in the bed-sediment thermographs using minimal infiltration data obtained from buried soil moisture sensors. The results indicate that, unlike visual and statistical methods, the ANN can identify ephemeral streamflow based on thermographs collected from any depth between 0 to 2 meters below ground surface.

H51B-0788 0830h POSTER

Comparison of Techniques for Estimating Baseflow of Streams in the Lower Apalachicola-Chattahoochee-Flint River Basin, Southwestern Georgia

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Since May 1998, the state of Georgia has experienced an extensive and prolonged drought. Streamflows in the southwestern portion of the state, in particular the lower Apalachicola-Chattahoochee-Flint (ACF) River Basin, have been reduced to less than 12 percent of normal, and ground-water levels have reached record or near-record lows. Baseflow contributions to streams were calculated to quantify the extent to which drought has affected streamflow in the basin. Field measurements of streamflow in October 1999 and in April and August 2000 were assumed to represent direct measurements of baseflow due to the lack of runoff during drought conditions. Computed estimates of baseflow from hydrograph separation and linear-regression analysis were compared with field measurements to determine the accuracy of each technique. Baseflow estimates during 1999-2000 were compared with baseflow estimates representing mean-annual conditions and above-normal precipitation (1994) to assess the effect of drought on baseflow.

Differences between computed baseflow estimates using hydrograph separation and field measurements ranged from 12.5 to 100 percent, although the estimation error in smaller basins was always less than 25 percent. Although linear-regression analysis has been proven to be useful for providing baseflow estimates in hydrogeologic settings such as the glacial till and outwash of Long Island, its usefulness in the karst geology of the lower ACF River Basin is limited. Differences between baseflow estimation using linear-regression analysis and field measurements typically were greater than 40-percent at each site.

Hydrograph separation was an effective technique for identifying drought conditions of streams by indicating relative increases in the proportion of groundwater contribution to streamflow (baseflow). As contributions to streamflow from overland flow, variable source flow, and interflow are reduced during drought, the percentage of ground-water discharge comprising total streamflow increases, even as ground-water levels decline, further reducing streamflow. In 1994, a relatively wet year, baseflow accounted for 37 to 56 percent of total streamflow; during the drought years of 1999-2000, baseflow accounted for 56 to 76 percent of total streamflow. During normal conditions, baseflow accounts for 54 to 67 percent of total streamflow. Hydrograph separation also was useful in estimating seasonal variations in ground-water discharge to streamflow.

H51B-0789 0830h POSTER

Modeling Low-Flow Sensitivity to Climate Variability and Forest Harvesting in the Willamette Basin: A Multi-scale Approach.

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In the mountainous region of the Pacific Northwest, underlying geologic and vegetation patterns, forest management practices and climate regimes at different elevations mediate the response of low flows occurring in late summer. Low-stream flow conditions, occurring during the warm, dry summers are critical to river ecosystem function and crucial to many aquatic and riparian species life cycles as well as human uses of streams. Understanding the different controls on low flow variability in this region requires a multi-scale perspective. This particular study is part of a larger strategy designed to use both empirical analysis and physically based, hydro-ecological modeling to disentangle the role that climate, geology and forest harvesting play in controlling low flows in 1st to 5th order watersheds within the Willamette basin. Our empirical analysis of summer low flow for a range of streams has shown that summer, unit-area discharge volumes are significantly lower for streams in the geologically distinct and low elevation Western Cascade versus High Cascade areas. This empirical analysis outlines large-scale regional variability. To assess and compare this with smaller scale variability, we use the RHESSys model (Regional Hydro-Ecologic Simulation System) to assess low flow behavior for small 1st order streams within the Western Cascade region. The goal is to examine low flow variability due to both climate and forest harvesting and recovery and place this in the context of regional scale analysis. We use multiple simulations to predict low flow volumes under cut and uncut conditions for wet/dry and warm/cool climate scenarios. Future work will replicate this study to examine 1st order watershed sensitivity within the contrasting High Cascade geologic region. The combined multi-scale empirical and modeling approach will then be used to provide a more comprehensive assessment of low flow patterns and sensitivity within this region.

H51B-0790 0830h POSTER

Effect of Barometric Pressure Change on Discharge of Boiling-Sand Springs and Consequent Baseflow of the Dismal River, Nebraska

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Barometric pressure change has been shown to affect groundwater movement, including baseflow to streams with a positive correlation. However, analysis of daily change of streamflow for the Dismal River in the Sand Hills of Nebraska shows a significant, negative correlation to daily barometric pressure change. The negative relationship can be explained by the hydraulic nature of boiling-sand springs found along the Dismal River. As this type of spring is not unique to the Dismal River, an inverse relationship of barometric pressure and baseflow should be expected in most rivers. The Dismal River is a baseflow stream with minimal contribution by surface runoff.

The boiling-sand springs are roughly circular vertical conduits, filled with sand held in suspension by rising groundwater discharge. Once the sand is in suspension, little energy is required to increase the spacing between sand particles so barometric pressure changes are transmitted with little modification down the conduit. Decreasing barometric pressure would be equivalent to dropping water levels in a large-diameter production well, increasing the rate of discharge to the well. The increasing discharge in the conduit with decreasing barometric pressure is readily accommodated by an increasing separation of sand particles leading to a greater effective cross-sectional area for flow. Calculations show that discharge of the boiling-sand springs can easily change by 20% with barometric pressure changes. Boiling-sand springs may contribute a significant part of the increase of baseflow reported during runoff events, which are usually associated with low-pressure systems.

H51B-0791 0830h POSTER

Determination of the Subsurface Water Balance Within a Semi-Arid Sky Island

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Whole basin water balances for semi-arid watersheds are complicated by the need to determine the mountain block recharge at higher elevations. Higher elevations are characterized by cooler, wetter, conditions than the lower elevation basins and have been proposed as a major contributor to basin recharge. This poster presents two point-scale methods for determining infiltration in soils at higher elevations and compares them to a larger scale sky island water budget. First, a physically-based heat and mass transport model (VS2DH) is applied to observed soil moisture and temperature profiles to determine infiltration fluxes past a depth of 24 cm. Secondly, a soil-vegetation-atmosphere transfer scheme the Common Land Model (CLM) is coupled with a multi-objective optimization routine to again quantify infiltration fluxes. Both models determine the most appropriate fluxes by minimizing differences between observed and modeled soil moisture and temperature profiles. These estimated point scale fluxes will be compared to a broader recharge water balance estimate based on runoff determined from gaging stations, evapotranspiration determined from an eddy correlation tower, and precipitation measured at the four sites within the basin. The difference between the larger areal recharge estimates and point scale infiltration estimates may be used to understand the processes controlling recharge beneath the soil profile at upper elevations in semi-arid basins.

H51B-0792 0830h POSTER

Uncertainty in Estimating Streamflow for a Semi-arid Shrubland Basin Using the MIKE-SHE Distributed Model

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Manual and automatic calibration approaches in distributed hydrological modeling have traditionally focused on identifying a single parameter set which optimizes the agreement between observed and estimated values. In recent years the concept of model equifinality has gained wide acceptance as a more appropriate framework for hydrological simulations. This concept suggests that acceptable model predictions might be achieved using different model structures or parameter sets and is particularly relevant to distributed hydrological models containing a large number of parameters. This study investigated the implications of parameter set equivalency for predicting streamflow response to fire and vegetation recovery in a semi-arid shrubland basin near Santa Barbara, California using the distributed MIKE-SHE model. Model calibration (conditioning) was performed using 1000 Monte Carlo-based simulations for a 20 year period encompassing a range of climatic conditions. Threshold values for two objective functions (coefficient of efficiency and water balance error) were used to classify each of the 1000 runs (i.e., parameter sets) as behavioral or non-behavioral. Model simulations for a 12 year validation period were run using the behavioral parameter sets, with results used to establish prediction intervals for validation period observations. Greater than 75 percent of the observations fell within the resulting prediction intervals.

The Monte Carlo-based results are compared to those obtained using a manual calibration approach and are discussed in the context of modeling post-fire streamflow dynamics in semi-arid environments.

H51B-0793 0830h POSTER

Water Residence Times and Runoff Sources Across an Urbanizing Gradient (Croton Water Supply Area, New York)

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Water residence times and nutrient budgets were measured in 3 small watersheds in the Croton water supply area, NY. The watersheds (less than 1km ^{2}) have different levels of urbanization (natural, semi-developed and fully developed), different mechanisms of runoff generation (quick flow on impervious surfaces and slow flow through the subsurface) and different watershed landscape characteristics (wet zones, hillslopes). Throughfall, stream water, soil water and groundwater in the saturated zone were sampled bi-weekly during a period of up to 2 years and analyzed for major chemical constituents, oxygen-18 content, and nitrogen species. Mean residence times of the stream water of about 30 weeks were estimated using Oxygen-18 and Helium-3/Tritium isotopes for all 3 watersheds. There was no significant difference in mean residence times among the three study watersheds, despite their different levels of urbanization. However, residence times from a few weeks up to ca 2 years vary within the watersheds, depending on the local runoff sources and their geographical conditions (riparian and hillslope topography, aquifer type). The runoff sources were quantified for selected streamwater and groundwater sampling sites using the end member mixing analysis technique (EMMA). The mixing analysis shows the impact of the runoff sources on runoff generation in the selected watersheds, i.e. it shows how big is the impact of urbanization on the runoff generation and how big is the natural control. These results may be useful in watershed management and planning of further urbanization in the Croton water supply area.

H51B-0794 0830h POSTER

An Evaluation of Real-Time Streamflow Forecasts From a Distributed, Physically Based, Hydrologic Model Applied in the Upper Rio Grande Basin.

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Different uses compete for the water resources of the Upper Rio Grande Basin including agriculture, municipalities, industry, recreation, ecology and water quality. For water operations management in the Upper Rio Grande, resource managers rely on accurate forecasts (both short and long term) of streamflow at several locations, or nodes on the river. In this study, the USGS Precipitation Runoff Modeling System (PRMS) is used to predict quantity of runoff in the headwater basin above the USGS streamflow gage near Del Norte, Colorado. Because fine-tuning of the PRMS can result in improved forecasts, predictions were made using three adaptations of the model: 1) low-spatial resolution, 2) high-spatial resolution, 3) using an alternate method of distributing climate variables throughout the basin. A post-forecast evaluation of the real-time streamflow forecasts is made via comparisons with forecasts made by the National Resources Conservation Service (NRCS). This study is highly collaborative between researchers at the Desert Research Institute (DRI) and the USGS as part of the NSF funded Center for Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA) efforts to improve models of snow distribution and snowmelt processes.

H51B-0795 0830h POSTER

River Networks for Global Flow Routing Modeling

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An algorithm for determining river networks for large-watershed flow routing modeling has been developed and implemented at a global and continental scale. After subdividing the terrain into square and identical cells by overlaying a coarse-resolution grid on top of it, the algorithm determines the downstream cell of each cell, and the distance along the meandering flow paths between them. Depending on the level of detail necessary for a specific application, the cell sizes can range from the hundreds of meters to the hundreds of kilometers. The method improves with respect to previously developed methods in that it uses fine-resolution vector river networks as the source of information of the flow patterns, rather than digital elevation models (DEMs). In general, it seems natural to use river networks to determine river networks of a coarser resolution, but, in addition to that, fine-resolution vector river networks tend to be more accurate than DEMs. Use of fine-resolution vector river networks has also the advantage that they capture, not only the topographic features of the terrain, but also the hydrologic ones, such as dry areas where no stream can be found even though a contributing drainage area can be delineated. River networks with resolutions of one degree for South America and 2.8125 degrees for the globe were determined to test the algorithm. Overall, the algorithm proved to capture well the flow and drainage divide patterns, and estimated basin areas were close to documented values. However, river lengths were consistently underpredicted, although a significant improvement was made when meandering factors a unique feature of this method for better estimation of flow distances were implemented.

H51B-0796 0830h POSTER

Streamflow Simulations for Major River Basins in China

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In this study, the land surface scheme (LSS) of VIC (Variable Infiltration Capacity) model is used to simulate streamflows of major river basins in China where the new surface runoff parameterization of VIC that represents both Horton and Dunne runoff generation mechanisms with the framework of considering subgrid spatial scale soil heterogeneity is applied. The entire area of China is represented by 2604 cells with a resolution of 60km60km for each cell. The VIC model is applied to each grid cell over each basin. A routing scheme is run offline which takes daily VIC surface and subsurface runoff as input to obtain model simulated streamflows at the outlets of study basins. Preparation of the forcing data, and soil and vegetation parameters needed by the VIC model for the entire area of China will be described, and some of the data issues will be addressed and discussed. The VIC streamflow simulations over a few river basins will be presented and compared with the observations.

H51B-0797 0830h POSTER

Implementation of a large-scale flow routing scheme in the Canadian Regional Climate Model (CRCM)

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Freshwater flux from river acts as an important forcing on the ocean. With lower density than ocean saltwater, freshwater from rivers affects thermohaline circulation and sea-ice formation at high-latitudes. Freshwater flux can be computed in a climate model by using runoff as an input into a flow routing model, which transfers runoff from the land surface to the continental edges. In addition to modeling freshwater flux for oceans, the streamflow obtained by the routing model can be used to assess the performance of atmospheric models on a climatological basis by comparisons with observed streamflow.

The variable velocity flow routing algorithm of Arora and Boer (1999, JGR-Atmos., 104, 30965-30979) is used to compute river flow in the Canadian Regional Climate Model (CRCM) (Caya and Laprise, 1999, Mon. Wea. Rev., 127, 341-362). The flow routing scheme consists of surface and groundwater reservoirs, which obtain daily estimates of surface runoff and drainage inputs, respectively simulated by the land surface scheme. The flow routing algorithm uses Mannings equation to estimate flow velocities. A rectangular river cross section is assumed with a fixed width and the variable depth is estimated using the amount of water in the river, slope, and river width.

Discretization of major river basins and flow directions for the North America domain are obtained at the polar stereographic resolution of the CRCM using 5 minute global river flow directions (Graham et al., 1999, WRR, 35, 583-587) as a template. Model runoff estimates from a global simulation of Variable Infiltration Capacity (VIC) hydrological model are use to validate the routing scheme. Routing models results show that compared to the unrouted runoff, the inclusion of flow routing improves comparison with observation-based streamflow estimates.

H51B-0798 0830h POSTER

Modeling Flood Response of Forested Appalachian Watersheds to Orographic Thunderstorms: Tygart Valley River, West Virginia

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The hydrology and hydrometeorology of flooding from orographic convective systems in the central Appalachian Tygart Valley River basin are examined using a distributed hydrologic model. Three adjacent subbasins (ranging in size from 380-700 km2) of the Tygart Valley River, each high gradient and predominately forested, are modeled for four storm events during the warm season of 1996 (16-17 May, 27-28 May, 18-19 July, 30-31 July). These storms produced flood peaks with return intervals in the range of 1.5-years to 200-years. Rainfall estimates are obtained from high-resolution (1 km, 5 minutes) rainfall fields derived from the WSR-88D radar in Charleston, WV, and 15 minute "unit values" discharge observations from USGS stream gaging stations are used for model calibration. The IFLOWS raingage network provides independent rainfall estimates and allows for bias correction of radar rainfall estimates. Differences between storms (storm return interval, rainrates, and the spatial and temporal distribution of rainfall) and between basins (drainage network structure and basin physiographic properties) are examined in an attempt to determine factors causing different flood response. The geomorpholocial instantaneous unit hydrograph (GIUH) is used to distinguish differences in flood response due to physical basin characteristics and those due to storm characteristics.

H51B-0799 0830h POSTER

Two-Dimensional Modeling of Flood Events in Denver, Colorado

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Advances in radar-rainfall estimation and two-dimensional physically-based runoff modeling offer tools to possibly mitigate the effects of flash flooding, reducing the potential for loss of life and property damage in urban catchments. The ability to model extreme hydrologic events in detail has been demonstrated using the CASC2D model developed by Julien et al. (1995) on numerous rural and urban watersheds (Ogden et. al., 2000). If models of this type are to be used for flash-flood warning in urban environments, it is imperative that input handling and display of hydrologic predictions make use of visualization tools and web technologies to facilitate the dissemination of information and interpretation of results in near real-time. The objective of this study is to determine how much detail in urban topography and drainage characteristics is needed for accurate simulations using data from urban flood events. Radar rainfall estimates, after rigorous quality control, are input to the hydrologic model to simulate flood events in Denver, Colorado. Comparison of simulated and observed discharges demonstrates the role of detailed distributed modeling in improving hydrologic predictions in urban settings. Data preparation and output display are facilitated using advanced server technology so the system can be implemented within a real-time environment.

H51B-0800 0830h POSTER

Classification of river networks

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Hydrological models are increasingly being used in large-scale river basin management. These models invariably require some element of calibration using hydrological data. This causes problems when applying models to river basins where no hydrological data exists (ungauged), a task that hydrologists are increasingly being called upon to undertake. The only practical approach to resolving this is regionalisation. Currently available regionalisation methods yield poor estimates of model parameters. The main problem is that their application relies on identifying groups of basins that are fairly similar in every part of their hydrological regime. Such groups (regions) tend to be very small. Consequently, the regional relationships, derived to infer model parameters for ungauged river basins from those calibrated for gauged river basins in the same region, are based on very little data and are unreliable. This paper outlines a new method for identifying regions, which differs from other currently available methods in two significant ways. The first is to discard the constraint that each basin only belongs to one group, and propose that each basin undergoes three independent classifications, one relative to each of the major components of the land phase hydrological cycle: interaction soil, vegetation and atmosphere; surface flow; groundwater flow. The second difference is in the methodology for objectively selecting which of the basin characteristics are the most appropriate classifiers. This paper focuses on the development of the surface-flow related classification. A new approach to classifying river networks according to their flow regime is proposed. It uses variables that can be derived easily from data stored in digital databases. For example, variables describing the topology of the network that have been derived automatically from digital Ordinance Survey maps. The objective method for selecting the best classification variables uses a comprehensive 1-D river network model within a Monte-Carlo framework.

H51B-0801 0830h POSTER

Models for scaling the variance of soil moisture

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Using remotely sensed maps of soil moisture, previous researchers have noted the apparent self-similar scaling of the variance of spatial soil moisture as the area represented by a single pixel changes. The most commonly used self-similar distributions in statistical literature are the fractional Brownian distribution and Levy stable distributions. These distributions are not appropriate models for the distribution of soil moisture, however, because they are nonstationary and in general unbounded, while real soil moisture content distributions are bounded by 0 and saturation and are often assumed to be stationary. We explore how the long-memory nature of soil moisture fields can give rise to the self-similarity, and what sort of self-similar distributions could be a possible model for soil moisture.

H51B-0802 0830h POSTER

Uncertainty analysis using a modified Point Estimate Method

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Rosenbluethsprobabilistic point estimate method is a computationally straightforward technique for uncertainty analysis of hydrologic engineering problems. It is known as capable of estimating statistical moment of any order of a model output involving several stochastic variables that are correlated or uncorrelated and symmetric or non-symmetric. However, in multivariate problems with more than three stochastic variables involved, the Rosenbluethsmethod is not able to provide a unique solution, rather an approximate solution to indeterminate problems. This is attributed to the fact that the number of unknowns to be solved is larger than the number of governing equations that are provided. This paper begins with a comprehensive review of various point estimate methods, with an emphasis on their differences and similarities in theory and application. An improved point estimate method is then proposed to circumvent this drawback and increase the computational efficiency as well. It is demonstrated that the proposed point estimate method preserves the capabilities of the Rosenbleths PE method but resolves the associated non-uniqueness problem.

H51B-0803 0830h POSTER

A Further Investigation of Baseflow Correlation to Estimate Low Streamflow Statistics at Ungauged River Sites

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Low streamflow estimates are required for a variety of water resource management purposes. When a historic streamflow record is available, low streamflow estimates may be obtained by a parametric or nonparametric frequency analysis. When no historic discharge is available, techniques for estimating low streamflow statistics are limited. For most application, regional regression models or drainage area scaling has been employed to estimate low streamflow statistics. These methods typically produce estimators with large standard errors. Another suggested method is baseflow correlation, where a nominal number of streamflow measurements are made at the ungauged river site during baseflow conditions. If these streamflows are highly correlated with concurrent streamflows from a nearby gauged river site, one may transfer information from the gauged site to the ungauged site to estimate low streamflow statistics at the ungauged site. A jack-knife resampling technique was used to examine the baseflow correlation method at 1300 river sites from the USGS's Hydro-Climatic Data Network (HCDN). The focus of this study was on estimating the 7-day, 10-year low streamflow (7Q10), a common design statistic. Results indicate that if the streamflow measurements are nearly independent in time and the correlation of the streamflows at the gauged and ungauged site are high, the baseflow correlation method can generally provide better estimates of low streamflow statistics than regional regression models. Here the use of multiple gauged river sites to estimate low streamflow statistics at a single ungauged site is also investigated. It is hoped that employing such regional information may further improve the baseflow correlation method.

H51B-0804 0830h POSTER

Assessing the Reliability of Regional Depth-Duration-Frequency Equations for Gauged and Ungauged Sites

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The study derives Regional Depth-Duration-Frequency (RDDF) equations for a wide region of northern-central Italy (37,200 km ^{2}) by following an adaptation of the approach originally proposed by *Alila* [WRR, 36(7), 2000]. The proposed RDDF equations have a rather simple structure and allow an estimation of the design storm, defined as the rainfall depth expected for a given storm duration and recurrence interval, in any location of the study area for storm durations from 1 to 24 hours and for recurrence intervals up to 100 years.

The reliability of the proposed RDDF equations represents the main concern of the study and it is assessed at two different levels. The first level considers the gauged sites and compares estimates of the design storm obtained with the RDDF equations with at-site estimates based upon the observed annual maximum series of rainfall depth and with design storm estimates resulting from a regional estimator recently developed for the study area through a Hierarchical Regional Approach (HRA) [*Gabriele and Arnell*, WRR, 27(6), 1991]. The second level performs a reliability assessment of the RDDF equations for ungauged sites by means of a jack-knife procedure. Using the HRA estimator as a reference term, the jack-knife procedure assesses the reliability of design storm estimates provided by the RDDF equations for a given location when dealing with the complete absence of pluviometric information. The results of the analysis show that the proposed RDDF equations represent practical and effective computational means for producing a first guess of the design storm at the available raingauges and reliable design storm estimates for ungauged locations.

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H51B-0805 0830h POSTER

Simple Scaling of Flood Quantiles and Individual Flood Peaks: Analysis of Data from a Small Hortonian Research Catchment

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We analyzed 15 years of runoff data collected at the 21.2 km^2 USDA-ARS Goodwin Creek Experimental Watershed in northern Mississippi to examine the spatial distribution of peak flows over a range of scales. This watershed data set provides a unique opportunity to study statistical self-similarity in peak flows because runoff is monitored at 14 sub-catchments ranging in size from 0.06 km^2 up to the scale of the entire watershed. Prior data-based studies using data from larger catchments have shown that simple scaling theory fails to describe the dynamical similarity in peak flows because there is a fundamental change in scaling behavior above and below a catchment area of approximately 100 km^2. We have determined that Goodwin Creek flood quantiles up to 20 year recurrence interval follow simple scaling theory with a scaling exponent of 0.87. Peak flows during single events are observed to follow simple scaling theory as well, with an average scaling exponent of 0.82, albeit with increased variance. Analysis shows that the primary reasons why peak flows are self-similar on Goodwin Creek are: over the time span of typical basin response precipitation is quite uniform; peak discharges from smaller sub-catchments are highly correlated to peak rainfall rates; the channel network is incised; fine soil textures are prevalent with high soil moisture states during the non-growing season; and, the groundwater table plays little or no role in runoff production. Increased likelihood of precipitation uniformity during annual-maximum runoff events promotes simple scaling of flood quantiles. Our findings are particularly relevant to peak flow predictions in smaller Hortonian catchments.

H51B-0806 0830h POSTER

A critical revision of the peak over threshold approach for flood frequency analysis

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In flood frequency modelling the peak over threshold (POT) procedure is considered a valid alternative to the usual analysis of annual maximum serie (AMS). The basic idea is to increase the available information by using more than one flood peak per year. However, in the practical applications ambiguous criteria for peak

selection affect the efficiency of the method. An objective procedure for peak identification is proposed here, with which some technical aspects that accompany the application of the POT can be reconsidered. In previous applications the average annual number of events Λ was limited to 2-4 in order to preserve peaks mutual independence. With the revised procedure it is found that larger Λ values, justified by physical and statistical reasoning, can be selected preserving the model basic hypotheses. The problems deriving from the interaction with seasonal runoff components and possible non-stationarities of the time series are also addressed by means of an evolution of the above peak selection method. The proposed procedure is applied to more than 30 time series of daily discharge, showing significant advantages towards the classical POT method.

H51B-0807 0830h POSTER

Flood frequency and magnitude relationships in the Cosumnes and Mokelumne drainage basins, Sierra Nevada, California

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Stream gages provide snapshots of a basins flood history. Many streams in a basin are ungaged. Statistical relations between recorded or computed values at stream gages are useful for estimating various discharges, such as bankfull or mean annual flood. Similarities in hydrologic, climatic, and basin characteristics in the Cosumnes and Mokelumne basins indicate that in-basin statistical relations would allow the development of equations for floods of various frequencies and magnitudes. Data for all US Geological Survey (unregulated) stream gages with greater than 10 years of record in the two basins were obtained.

The methods used are based on the Log-Pearson type III distribution, and include outlier screening, historical adjustment, and two-station comparison. The two station comparison method, where information at a long-term gage is used to adjust the statistics of a short-term gage, improved over-all results for several short-term gages.

Several regression equations relating drainage area and flood magnitude (discharge), such as bankfull discharge (approximately the 1.5 year flood,) mean annual flood, (2.33 year flood), and the 10 year flood were developed. The r2 , F-statistic and residual analysis for each regression indicate good results. The 1.5, 2.33, or 10 year flood on any ungaged (and unregulated) stream in either of the river basins may be estimated with reasonable accuracy using only drainage area..

Future work will include use of a 10-meter digital elevation model that includes preciptitation, vegetation, and soil layers–to determine other explanatory variables. Observable curvature developing in the discharge versus drainage area relations for floods of lesser frequency is expected to be explained in a multivariate analysis.

H51B-0808 0830h POSTER

Coupling Geomorphologic Analysis and Multiscaling Properties of Hydraulic Geometry for Runoff Routing in Ungaged Catchments: The Geomorphologic Nonlinear Reservoirs in Network (GNRN) Concept

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The dependencies between channel properties and river flows have been observed for a long time, and empirically described by the so-called hydraulic geometry (HG) relationships; however, it is only recently that systematic attempts have been made to consider these relationships in the context of hydrologic response. Based on empirical evidence that the parameters of the HG relationships are not constant over a basin but change as a function of contributing area (scale), we postulate a multiscaling model for HG variables (width, depth, cross-sectional area, mean velocity and discharge) and revise the HG relationships to reflect scale-dependency. Data from 85 streamflow gaging stations in Central US, Oklahoma and Kansas, are used to verify the proposed multiscaling model and the revised HG relationships. The revised HG relationships are then combined with geomorphologic analysis of a stream network via a network of nonlinear reservoirs concept of runoff routing, to develop a model termed Geomorphologic Nonlinear Reservoirs in Network (GNRN) for runoff routing in ungaged catchments. Preliminary results are encouraging and indicate the potential of the proposed methodology for (a) runoff prediction in ungaged catchments via regionalization of the revised HG relationships and (b) better understanding of the nonlinear effects of the temporal variability of forcing and topological structure of the river network on streamflow dynamics.

H51B-0809 0830h POSTER

Morphometric Discharge Relationships in the Cosumnes River Drainage Basin, Sierra Nevada, California

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Hydrographic similarities between disparate gaging stations in the Consumnes River drainage basin suggest that it may be possible to extend stream gage records in areas with limited or missing records. This has led to an analysis of the relationship between recorded daily discharge values and bankfull channel conditions in the basin using USGS gage data from three sites in the basin [11335000 Cosumnes River at Michigan Bar (MBAR - period of record 1907-2002), 11333500 North Fork Cosumnes near El Dorado (NFELDO - period of record 1911-1941 and 1948-1987) and the 11334200 Middle Fork Cosumnes near Somerset (MFSOM - period of record 1957-1971)], 3-day mean discharge values and bank-full conditions (discharge recurrence interval of 1.5 years) were calculated.

Utilizing the bank-full discharge of the mainstem gage (MBAR) as a threshold, we compared discharge values between MBAR and two of its tributaries (NFELDO and MFSOM) and observed strong linear trends in the data sets. Mathematical expressions were derived to characterize the relations between the individual tributaries and the mainstem gage. When calibrated against the complete gage records of the tributaries we encountered overall error rates of less than 5 percent from both tributary data sets. This suggests that it is possible to extend stream gage records in areas with limited existing records or where occasional activiation and de-activation of gage sites result in incomplete long-term records.

H51B-0810 0830h POSTER

Sedimentation in Rio La Venta Canyon in Netzahualcoyotl Reservoir, Chiapas, Mexico

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Sedimentation of Rio La Venta as it enters the Netzahualcoyotl Reservoir in Chiapas, Mexico, threatens a unique part of the aquatic ecosystem. Rio La Venta enters the reservoir via a narrow canyon about 16 km long with spectacular, near-vertical limestone bluffs up to 320 m high and inhabited by the flora and fauna of a pristine tropical forest. Karst terrain underlies most of the Rio La Venta basin in the vicinity of the reservoir, while deeply weathered granitic terrain underlies the Rio Negro basin, and the headwaters of the Rio La Venta to the south. The Rio Negro joins Rio La Venta 3 km downstream of the upper limit of the reservoir and delivers the bulk of the total clastic sediment (mostly sand and finer material). The canyon and much of the contributing basin lie within the Reserva de la Biosfera, Selva El Ocote, administered by the Comision Nacional de Areas Naturales Protegidas, part of the Secretaria de Medioambiente y Recursos Naturales. The Klamath National Forest Forest has cooperated with its Mexican counterparts since 1993 in natural resource management, neo-tropical bird inventories, wildfire management, and more recently in watershed analyses.

Rates of sedimentation are estimated from bathymetric surveys conducted in March, 2002. A longitudinal profile down the inundated canyon during a high reservoir level shows an inflection from a slope of 0.0017 to one of 0.0075 at 7.2 km downstream of the mouth of Rio Negro. The bed elevation at this point corresponds to the lowest reservoir level, suggesting that the gentler sloping bed upstream is formed by fluvial processes during drawdown and that downstream by pluvial processes. Using accounts that boats could access Rio Negro during low water levels in 1984, we estimate an annual sedimentation rate of roughly 3 million cubic meters per year. This suggests that boats might no longer be able to access the most spectacular section of canyon upstream of Rio Negro within a decade, depending on how the depositional profile develops. Additionally, canyon filling will change the aquatic ecology of the river and the reservoir, and result in loss of fish habitat. A monitoring program is in place to answer this critical question.

H51B-0811 0830h POSTER

Monitoring Stream Stage, Sediment Transport, and Salinity With Time Domain Reflectometry

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The versatility of time domain reflectometry (TDR) is evidenced by the variety of applications for which this technique has been employed. TDR is widely used in microchip analysis, locating breaks in long transmission lines, monitoring deformation of geologic and engineered materials, and for soil moisture sensing. Here, we propose TDR for remote, real-time monitoring of the quantity and quality of stream flows. TDR operates by propagating an electromagnetic pulse down a transmission line, while monitoring the returned signal. The pulse is susceptible to reflection by dielectric discontinuities (i.e., air-water and water-sediment interfaces) and attenuation by the dielectric and conductance of the medium surrounding the transmission line. Thus, TDR holds promise as an integrated method for measuring the depth of water, depth of scour, sediment load, and salinity of flowing streams.

Laboratory experiments have been conducted to demonstrate the capabilities of the TDR within this context. Controlled experiments were first conducted in plastic tanks with a TDR probe secured to the bottom. The next phase of experiments were conducted with flowing water in which the TDR probe was secured in a sediment erosion flume. Tank and flume experiments progressed by taking TDR readings while sequentially varying 1) depth of water, 2) depth of sediment covering the probe, 3) sediment concentration in the flowing water, 4) salinity, and 5) discharge rate. Measured TDR traces were then interpreted and modeled using a multisection model based on the S_{11} scatter function and Cole-Cole parameters for dielectric dispersion and loss (e.g., Feng et al., WRR 35(8), 1999).

Results demonstrated predictable and quantifiable changes in the TDR traces with changes in position of the air/water and sediment/water interfaces along the length of the TDR probe, as well as changes in salinity. The multisection model was also found to closely match the measured TDR traces. No quantifiable changes in TDR response were noted with changing discharge rate in the flume experiments. Efforts are currently underway to establish a TDR monitoring site on a natural watercourse.

H51B-0812 0830h POSTER

Water content measurements in the deep vadose zone using a new design and installation technique of TDR probes

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A common method for obtaining continuous water content data in unsaturated soil relies on Time Domain Reflectometry (TDR). However, TDR probes are difficult to install in deep soil horizons, and often the soil is disturbed in the process. Given the importance of accurate determination of water content in many vadose zone monitoring programs, we have developed a new design and installation technique for TDR probes, enabling water content monitoring of deep vadose zone horizons in relatively undisturbed soil conditions to any desired depth. The method uses flat, flexible waveguides made of stainless foil strips, attached to the ceiling of a slanted borehole. The TDR waveguides are attached to a flexible sleeve made of rubber or PVC liner, filled with a liquid resin. Prior to its curing, the resin (e.g., a two-component urethane) generates a hydrostatic pressure that forces the flexible waveguides against the borehole wall, ensuring a close fit to the irregular shape of the borehole walls. The attachment and installation can be performed using either a standard TDR technique or a water content reflectometer (e.g. model CS505, Campbell Scientific, Inc., Logan, UT), which is sampled using a micrologger. Laboratory calibration results from both probes indicate high sensitivity to water content changes and high correlation coefficients (r2 = .988 using 2nd order form with standard TDR probe, and r2 = .989 for linear curve with CS-505). The probe was then installed in boreholes at two locations. One was an agricultural field subjected to three episodes of flood irrigation, and the second was in an ephemeral wash in the Mojave Desert, where we were studying the stability of long-term measurements in an area without significant rainfall. Data from the first experiments showed that the flexible probes detected changes in water contents for each flood episode to a depth of 2.9 m, including the rise in a shallow water table elevation. The results of the second experiment shows only steady water content reading with minor water content changes as the experimental site is located in desert area and yet no significant rain event occurred since the probes were installed. The experimental results shows that the method is reliable and capable of providing accurate water content measurements in deep vadose zone horizons.

H51B-0813 0830h POSTER

Effects of an Alpine Ski Resort on Hydrology and Water Quality in the Northeastern U.S.: Preliminary Findings from a Field Study

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High elevation, forested watersheds are particularly vulnerable to stresses from development. Steep slopes and thin soils rapidly transmit water, nutrients and sediment when disturbed by logging, road construction or other activities associated with development. The effects of forest harvesting practices on streamflow and water quality in high-elevation, forested watersheds have been well studied and provide relevant information about the susceptibility of these ecosystems to anthropogenic disturbance. Few studies have directly addressed the hydrologic or water quality effects of ski resort development on mountain streams, and these studies draw almost entirely from western U.S. examples. Ski resorts in the eastern U.S. face particular development pressures. Transient and unpredictable snow conditions generate extensive need for snowmaking. Competitive economic pressure has motivated plans for slope-side village development and summer recreation facilities at many eastern U.S. ski resorts.

Here, we report preliminary findings of a recently initiated paired-watershed study to examine the effects of alpine ski area development on water quantity and quality. Our study area is located on the eastern slope of Mt. Mansfield, Vermont, and includes the basins of Ranch Brook (9.6 sq km) and West Branch (11.7 sq km). Ranch Brook is undeveloped, except for a network of cross-country ski trails and unsurfaced access roads, and serves as our control watershed. West Branch encompasses nearly an entire major ski resort, with an extensive network of alpine ski lifts and trails, day lodges, snowmaking facilities, and vacation homes. A major expansion of resort facilities and ski trails has recently received state approval. Our preliminary analysis indicates distinct differences in runoff and water quality between the two basins. Differences in basin hydrographs suggest that ski trails alter the timing and magnitude of runoff, particularly during spring snowmelt. Elevated concentrations of total suspended solids in West Branch streamwater suggest that exposed surfaces (trails, parking lots) may be important sources of sediment in the ski resort basin. Streamwater chemistry at West Branch also suggests contamination by deicing salts. Variability in summer low flows between the two basins indicates unexplained differences in precipitation capture or groundwater loss in the basins and must be resolved in future analysis. These findings provide important baseline information for ski area management in the eastern U.S., where field studies have been sparse. Our future plans include hydrologic modeling to assess the effects of current development and various future development scenarios on streamflow and water quality.

H51B-0814 0830h POSTER

Assessment of the Unintentional Reuse of Municipal Wastewater

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Many surface waters that receive wastewater effluent also serve as source waters for drinking water treatment plants. Recent research has shown that a number of previously undiscovered wastewater-derived contaminants are present in these surface waters, including pharmaceuticals and human hormones, several of which are suspected carcinogens or endocrine disrupters and are, as of yet, unregulated through drinking water standards. This research has been designed to determine the extent of contamination of specific wastewater-derived contaminants in surface water bodies that both receive wastewater effluent and serve as a source of drinking water to a sizeable population. We are testing the hypothesis that surface water supplies during low flow are potentially of worse quality than carefully monitored reclaimed water.

The first phase of our research involves: (1) the selection of sites for study; (2) a hydrologic analysis of the selected sites to determine average flow of the source water during median- and low-flow conditions; and (3) the development and testing of chemical analyses, including both conservative and reactive tracers that have been studied in microcosms and wetlands for attenuation rates. The second phase involves the development and use of the hydrologic model QUAL2E to simulate each of the selected watersheds in order to estimate potential stream water quality impairments at the drinking water intake at each site. The results of the model are verified with field sampling at designated locations at each site. We expect to identify several critical river basins where surface water at the drinking water intake contains sufficient wastewater-derived contaminants to warrant concern. If wastewater-derived contaminants are detected, we will estimate the average annual exposure of consumers of this water. We will compare these expected and actual concentrations with typical constituent concentrations found in wastewater that has undergone advanced treatment for reclamation. We may demonstrate that the surface water supplies during low flow are actually of worse quality than carefully monitored reclaimed water.

H51B-0815 0830h POSTER

A Rigorous Treatment of Interactions Between Various Media in First Principle, Physics-based Flow and Transport Modeling in Watersheds

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In the past 30 years, parametric-based models (the most famous one is the HSPF) have been employed for watershed modeling to calculate surface runoff and total maximum daily loads (TMDL). Evolved from the pioneer model STANFORD WATERSHED IV, HSPF and similar parametric-based models have dominated watershed simulations in the past 20 years. Physics-based, process-level chemical transport and hydrological models on a watershed scale have been practically nonexistent until recently. It has long been recognized that only the first principle, physics-based, process-level fluid flow and sediment and chemical transport models have the potential to further the understanding of the fundamental flow and transport processes that take place in nature watersheds, and give mechanistic predictions. However, there are severe limitations with first principle, physics-based models on a watershed scale that inhibit their use. These are, among other things, the excessive demand of computational time and the ad hoc approaches of coupling between various media. This paper presents a rigorous coupling strategy for interactions among rivers/streams/canal networks, overland regime, and subsurface media. Introductions of non-physics parameters such as linkage terms are avoided. Example problems will be employed to illustrate the importance of rigorous coupling.

H51B-0816 0830h POSTER

Mass Balance Analyses of Flushing, Evaporation, Infiltration, and Biological Activity in California Park Lakes, Butte County, California

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California Park Lakes are retained by dams on Dead Horse Slough, an ephemeral stream network, which flows over volcanic/sedimentary rocks of the Tuscan Formation at the eastern margin of the Sacramento Valley, Butte County, California. Surface area of the lakes is approximately 0.2 km^2, maximum depth is 8 m, and approximate lake volume is 700,000 m^3. Flow rate and depth measurements in Dead Horse Slough indicate that discharges associated with winter storms flush the lakes repeatedly. During dry summer months no surface water discharges from the lakes and water is pumped from the underlying aquifer to maintain the water level. Average pumping rates are approximately 1250 m^3/day. Surface and storm drain runoff, mainly from nearby lawn irrigation, also supply water at fluctuating rates estimated to equal a fraction (e.g., 35 percent) of well water supply. Reported pan evaporation data indicate that summer evaporation from lake surfaces is 1000 to 1500 m^3/day. Thus, the estimated evaporation rate approximately equals the well water and runoff supply rate. Periodic chemical analyses of water supplies and lake water have been conducted primarily to evaluate nutrient sources. Typical nitrate and chloride concentrations are 2 to 10 mg/liter, and typical phosphate concentrations are 0.2 to 1 mg/liter. Chloride concentrations in lake water during summer 2002 increased slightly corresponding closely to mass balance calculations for evaporative concentration. Infiltration (including leakage through the terminal dam) is small relative to evaporation and difficult to measure within the uncertainty of chloride measurements and water mass balance estimates. Lake concentrations of nitrate and phosphate are generally lower than source water concentrations consistent with biological consumption. Mass balance analyses of dissolved nutrients in lakes and water sources compared to chloride provide a measure of the rate of biological activity in the lakes, which is a water quality management issue. Characterization of flushing, evaporation, and biological activity in California Park Lakes using water and chemical mass balance analyses contributes to water quality management and provides constraints on infiltration into the Tuscan Formation, which is the primary regional aquifer for domestic water supplies.

H51B-0817 0830h POSTER

Controlling Vadose Zone Hydrologic Processes in Traditional Dryland Farming Technology on the Hopi Indian Reservation, Arizona

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Due to extreme aridity, it is necessary for Hopi farmers to minimize moisture losses in non-irrigated fields. New data indicate that the traditional Hopi farmer reduces moisture loss by controlling the geomorphic processes that affect vadose zone hydrology. Fields are located on naturally stratified soils that comprise barriers to vertical drainage and bare soil evaporation. All cultivation activities serve to preserve or enhance the soil profile. Field clearing and weed removal eliminate competitors for water without disturbing natural soil profiles, and reduce evapotranspiration. Maintenance of windbreaks control eolian transport of sand mulch and improve soils of nearby areas, therefore, allowing field expansion. Planting techniques place seeds into zones of optimal moisture, while protecting sand mulch. Planting in widely spaced clumps provides each clump with water from a large, sealed volume of soil.

This study characterized the 2002 seasonal hydrology of the hydrogeologic framework layers of two Hopi farms, comprised of mixed pedogenic, eolian, and fluvial deposits overlying Mancos Shale bedrock, using

gypsum block, precipitation, temperature, wind, relative humidity, and solar radiation sensors recorded on a 30-minute interval, and supplementary rain gauges recorded on a 5-minute interval. Given the 2002 severe drought year in northeast Arizona, the correlation of the hydrogeologic dynamics with the locations of failed crops is striking. Unsaturated zone model simulations of the seasonal measurements were then conducted, and future predictions based on different moisture inputs of wet and normal year estimates were made regarding future crop success. An accurate conceptual model using integrated systems analysis was imperative for successful mathematical model simulations of the two Hopi fields.

H51B-0818 0830h POSTER

Hydrological Controls on Nutrient Concentrations and Fluxes in Agricultural Catchments

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This investigation into diffuse agricultural pollution and the hydrological controls that exert a strong influence on both nutrient concentrations and fluxes, was conducted in an intensively farmed lowland catchment in north-east Scotland. The study focuses on spatial and seasonal variations in nutrient concentrations and fluxes at the catchment scale, over a 15-month period. The water quality of the 14.5 km2 Newmills Burn catchment has relatively high nutrient levels with mean concentrations of NO3-N and NH3-N at 6.09 mg/l and 0.28 mg/l respectively. Average PO4-P concentrations are 0.06 mg/l. Over short timescales nutrient concentrations and fluxes are greatest during storm events when PO4-P and NH3-N are mobilised by overland flow in riparian areas, where soils have been compacted by livestock or machinery. Delivery of deeper soil water in subsurface storm flow, facilitated by agricultural under-drainage, produces a marked increase in NO3-N (6.9 mg/l) concentrations on the hydrograph recession limb. A more detailed insight into the catchment response to storm events, and in particular the response of the hydrological pathways which provide the main sources of runoff during storm events, was gained by sampling stream water at 2-hourly intervals during 5 events. End Member Mixing Analysis (EMMA) was carried out using event specific end-member chemistries to differentiate three catchment-scale hydrological pathways (overland flow, subsurface storm flow, groundwater flow) on the basis of observed Si and NO3-N concentrations in sampled source waters. Results show that overland flow generally dominates the storm peak and provides the main flow path by which P is transferred to stream channels during storm events, whilst subsurface storm flows usually dominate the storm hydrograph volumetrically and route NO3-rich soil water to the stream. The study shows that altering hydrological pathways in a catchment can have implications for nutrient management. Whilst buffer strips can reduce the delivery of NH3-N and PO4-P by overland flow to stream channels during storm events, the management of N-rich storm runoff as NO3 via sub-surface drains would require significant interference with the drainage network. This could have a negative impact on agricultural production in the catchment.

H51B-0819 0830h POSTER

Demans-Side Drip Irrigation Method

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Demand-Side irrigation principle had been stated by Fok (in AGU 2001 Fall Meeting)that the water demand by crop determines the starting and stoping of the irrigation water flow. In other words, when the crop needs water, its signal will cause the irrigation water to flow. As soon as crop's water demand has been satisfied, the irrigation will be turned off. This innovative demand-side irrigation principle is logically formulated, it can save great amount of irrigation water from the current Supply-Side irrigation practices. Among the common irrigation methods, drip irrigation method is selected for study in this paper. Because the drip irrigation method has the hardware most suitable for modification into the demand-side irrigation practices. Drip irrigation systems have the water-feeding lines that are placed in the crop's root zone. When the crop is growing, its root system will suck-up water, then the soil-moisture will be lowered. If a sensor of the soil-moisture content(e.g. a tensiometer) is in place, it can detect the increased in soil-moisture tension. A signal can be obtained to cause the release of the drip irrigation water into the soil-profile. When soil-moisture is replenished, the soil-moisture tension will be lowered to a level that will signal the drip irrigation flow to be truned off. This paper will present some of the remote sensing techniques for the demand-side drip irrigation method.

H51B-0820 0830h POSTER

Fluid Mechanics and Hydrology

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Present day Engineers need to understand water, its properties, its distribution as well as its movement. Certain engineering disciplines may require a course in Hydraulics and Hydrology. However, most other disciplines require courses in Fluid Mechanics and Thermodynamics. The author believes Hydrology is an essential knowledge that most engineers should possess, regardless of their discipline. Water is consumed or circulated in huge quantities in certain types of industries and location of water resources / supply may play a key role in the selection of a future factory site. Pulp and Paper Manufacturing Industries, Chemical Industries, Heat Treatment Facilities are just a few that one can mention. A typical Engineering Fluid Mechanics Course normally covers the broad discipline of Engineering Mechanics that is concerned with the behavior of Liquids and gases at rest or in motion. Water, of course is one of the liquids discussed. Regardless, Engineers are totally ignorant of the subject matter of Hydrology or the Hydrologic Cycle and their importance in the twenty-first century Engineering Environment. In this short paper, the author outlines the methods of successfully incorporating Hydrology into an Engineering Fluid Mechanics Course.

H51B-0821 0830h POSTER

Watershed-Scale Hydrogeologic Analysis and Paleohydrologic Modeling of Prehistoric Settlement Systems in the Canyon of the Ancients Region, Southwest Colorado

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The purpose of this NSF biocomplexity study is to model the paleohydrology for human settlement systems in the Canyon of the Ancients Region, Colorado and Utah. Specifically, our intent is to understand and model the lagged response of the water resources in our study area to changes in climate and impact of human occupation by understanding and modeling the modern hydrologic systems, and by studying and modeling coupled human/natural landscapes and hydrologic systems over very long periods of time. The broad hypothesis is that changing distributions of water sources, including flow quantities, during the late pre-Hispanic occupation affected the settlement systems and significantly contributed to the depopulation of the area. In this context, the approach is to: 1) conceptualize and characterize the modern hydrologic system, using the integrated, multidisciplinary hierarchical systems analysis of Kolm et. al. (1993, 1999, 2000); 2) develop solid and mathematical models to visualize and quantify the modern hydrogeology and hydrologic system on a watershed-scale; 3) test the mathematical models by incorporating known hydrologic system stresses that have occurred within historic times; and 4) develop scenarios of the paleohydrologic system based on paleoclimate records, using tree ring data and paleo jet stream analysis for identifying the relative roles of climate and human-induced stresses. This paper will present the progress to date of the conceptual model of the modern hydrologic system of southwest Colorado based on the characterization of the hydrologic system, the hydrogeologic solid block model, and the mathematical flow model.

H51B-0822 0830h POSTER

What is the Constitutive Equation for One-Dimensional Open-Channel Flow?

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The Manning equation is almost universally accepted as the constitutive equation for modeling one-dimensional (1-D), rough, turbulent, open-channel flows. However, the fact that one can compute Manning's n from measured quantities and use the Manning equation to model water-surface profiles does not prove that it is correct. Indeed, the Manning equation violates at least two of the principles that should be satisfied by a constitutive relation (Bear 1972): (1) consistency with principles of momentum balance and (2) dimensional homogeneity. The formulation of the Manning equation rests on shaky grounds - an "eyeball" approximation of a limited set of observations modifying the force-balance relations developed by Chezy. Furthermore, even the Chezy equation is based on the dimensionally-motivated assumption that resistance is proportional to velocity squared (U^2). As Leopold et al. (1962) pointed out, that assumption may only be true if the flow boundary does not change with U, which is true for pipe flow but not open channels. At any point, a rough turbulent steady flow must satisfy three relations: continuity, the 1-D energy equation, and a constitutive relation, which together dictate the shape of the water-surface profile. Different constitutive relations will predict different profiles. This paper is an initial exploration of the implications of the Manning equation and several possible alternative constitutive equations for the computation of water-surface profiles in a rectangular flume. The computed profiles are compared and tested for conformity with Hamilton's principle: "The path taken by a dynamical system is that which minimizes the time integral of the difference between kinetic and potential energy." Ultimately, these profiles must be compared with actual profiles to determine which is consistent with observation.

H51B-0823 0830h POSTER

Practical Considerations for an International Watershed Research Network W. R. Osterkamp and John R. Gray

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An International Watershed Research Network is an initial project of the Sino-U. S. Centers for Soil and Water Conservation and Environmental Protection. The network will provide a database for research personnel participating in the Centers, as well as the global community. The database fundamental to the successful operation of the Centers. The need to (a) identify and select candidate watersheds for the network, (b) develop acceptable, and preferably, consistent techniques for the collection and dissemination of data, and (c) specify other data sources on erosion, sediment transport, hydrology, and ancillary information of probable interest/use through the Centers seems essential prior to initiation of the network.

H51B-0824 0830h POSTER

Experimental Drainage Basins in Israel

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Within the hyper-arid to semiarid areas of Israel are three experimental drainage basins. They are the Nahal (stream in Hebrew) Yael, subdivided into five subbasins, Rahaf-Qanna'im (main and tributary, respectively) and Eshtemoa. These basins vary in drainage area and climate, and in monitoring duration and type. All are drained by gravel-bed channels. As the size of monitored drainage area is limited, 3-4 additional representative basins covering areas of 300, 1000, 2000 and 8000 square kilometers will likely be implemented in the next decade. The basins have precipitation, runoff, sediment and fluviomorphological records. Each was conceived for differing purposes, but all share the common two objectives for the continuous monitoring:

1. Many hydrological issues may be approached if, and only if, there are prototype databases on a wide spectrum of hydrological processes; and

2. There is a need for long-term records to assess large floods and subsequent hydrologic and geomorphic recovery.

Lessons derived from a large number of research projects on these experimental basins focus on characteristics of runoff in arid climates. For example, the effect of the spatial distribution of rainfall on runoff generation becomes increasingly important with aridity. Rainfall angle on hillslopes and storm intensity and direction derived from rainfall recorders and radar backscatter are crucial for explanation of runoff response. Runoff hydrographs tend to have more bores, shorter-duration peaks, briefer recessions, longer dry periods, and are more variable in terms of flood volume and peaks with increased aridity. Suspended-sediment fluxes, yields and concentrations are relatively large in the semiarid realm, reaching maxima at the beginning of a flood season and after long dry spells. Bedload fluxes are exceptionally high from dryland basins in which hillslopes are minimally vegetated and where bedload transport takes place in channels lacking an armor layer.

Bedload/suspended-sediment load ratios increase with aridity. Bedload yield may represent up to 70% of the total load. Hillslope to channel connectivity is high in drylands. In the hyperarid region suspended-sediment sources are hillslopes and the coarser, sandy fraction of the channel bedmaterial. The depth of channel bed activity is indicated by a fluvio-pedogenic unit beneath the channel surface.

National and regional hydrological research needs will dictate future global monitoring in experimental basins. International collaboration may bring about considerable cost reduction by exclusion of monitoring aspects that can be evaluated based on the monitoring in other, similar conditions. Advanced international collaboration on validation and calibration of and consistency in monitoring means, as well as syntheses of lessons derived from international collaboration, such as from an International Watershed Research Network, are required for maximizing our understanding of water and sediment responses in varied global regions.

H51C MCC: 120 Friday 0830h

Using Groundwater Models to Guide Field Data Collection I

Presiding: **C Tiedeman,** U.S. Geological Survey**; B Wagner,** U.S. Geological Survey

H51C-01 0835h INVITED

Use of Flow and Transport Models for Experimental Design for Model Calibration and Monitoring Network Design

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Groundwater flow and contaminant transport in subsurface are governed by partial differential equations. With appropriate initial and boundary conditions specified, the governing equations are solved by either the finite-difference or the finite-element method. Groundwater models can be used for prediction as well as for guiding field data collection. This paper reviews the use of such models for experimental design for model calibration and monitoring network design for plume characterization. In general, experimental design concerns with the selection of a set of experimental conditions, including data collection strategies, such that the information collected will minimize either the parameter uncertainty in the parameter space or the prediction uncertainty in the prediction space. The minimization is subject to a set of constraints, most importantly, the budgetary constraint. To estimate the uncertainty in either the parameter or the prediction space, it requires the use of the flow and transport models to derive the covariance matrix of the model parameters. To improve the efficiency and reliability of a remediation design, the spread of a contaminant plume in time and space must be predicted by the flow and transport models and monitored accurately. Experimental design techniques have been applied to construct groundwater quality monitoring networks that maximize plume characterization while minimizing the construction and sampling costs.

H51C-02 0900h INVITED

Optimization Modeling to Guide Field Data Collection

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As part of on-going efforts to demonstrate the applicability and advantages of the simulation-optimization approach for reducing groundwater remediation costs under general field conditions, a series of optimization modeling projects was recently conducted at several Superfund sites in Massachusetts, Oregon, Utah and Nebraska. The optimization modeling at each site provides a logical framework for assessing the data gaps and guiding further data collection. This is done by evaluating the sensitivity of the cost function to various model parameters, and moreover, by incorporating the decision variables associated with a sampling network directly into the optimization formulation. In this presentation we will provide an overview of the optimization modeling efforts, demonstrate the use of the simulation-optimization model to guide field data collection, and discuss the challenges and research needs in field-scale optimization modeling.

URL: http://hydro.geo.ua.edu

H51C-03 0925h INVITED

Using Ground-Water Models to Guide Field Data Collection: Management Decisions Impacted by Groundwater-Surface Water Interactions

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Groundwater models provide a mechanism for linking management options with field data collection activities. This linkage allows cross-disciplinary integration of management and technical decisions. Models used in this framework must meet unique objectives in terms of tradeoffs between complexity and transparency. Management decision models provide constraints and guidelines related to the complexity and data requirements for the groundwater models. Issues related to groundwater-surface water interactions spawned by salmon recovery activities in the Pacific Northwest are used to illustrate these objectives and model applications.

H51C-04 0950h

Ground-water modeling and the installation of deep multiple-well monitoring sites in the Central and West Coast Basins, Los Angeles County, California

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An ongoing regional study of the geohydrology and geochemistry of the Central and West Coast Basins in Los Angeles County, California has iteratively combined the drilling of deep multiple-well monitoring sites with groundwater modeling. The monitoring sites are generally between 1,000 and 1,500 ft in depth and consist of 4-6 piezometers installed within a single borehole that provide depth-dependent geohydrologic data. The U.S. Geological Survey (USGS) and the Water Replenishment District of Southern California (WRDSC) drilled four monitoring sites at the beginning of the cooperative study. The data from these sites, along with data compiled from existing wells, formed the basis for developing a preliminary multi-aquifer groundwater simulation model. Initial model simulations were then used to help prioritize new drilling locations where additional geohydrologic data were needed to more accurately simulate the complex system. Additional drilling, updating the regional simulation model, and new modeling-including development of particle tracking, simulation-optimization, and solute transport models-have proceeded iteratively. As of September, 2002, 34 multiple-well monitoring sites (162 piezometers) have been constructed.

The new modeling, which focuses on seawater intrusion, has identified the need for more detailed data on sequence stratigraphy, geometries of confining beds and high permeability zones, and pore-water chemistry. In response to this need, continuous coring has been conducted cooperatively by the USGS, WRDSC, and Los Angeles County Department of Public Works at six of the monitoring sites completed thus far.

H51C-05 1030h

The Use of Genetic Algorithms as an Inverse Technique to Guide the Design and Implementation of Research at a Test Site in Shelby County, Tennessee

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The Shelby Farms test site in Shelby County, Tennessee is being developed to better understand recharge hydraulics to the Memphis aquifer in areas where leakage through an overlying aquitard occurs. The site is unique in that it demonstrates many opportunities for interdisciplinary research regarding environmental tracers, anthropogenic impacts and inverse modeling. The objective of the research funding the development of the test site is to better understand the groundwater hydrology and hydraulics between a shallow alluvial aquifer and the Memphis aquifer given an area of leakage, defined as an aquitard window. The site is situated in an area on the boundary of a highly developed urban area and is currently being used by an agricultural research agency and a local recreational park authority. Also, an abandoned landfill is situated to the immediate south of the window location. Previous research by the USGS determined the location of the aquitard window subsequent to the landfill closure. Inverse modeling using a genetic algorithm approach has identified the likely extents of the area of the window given an interaquifer accretion rate. These results, coupled with additional fieldwork, have been used to guide the direction of the field studies and the overall design of the research project. This additional work has encompassed the drilling of additional monitoring wells in nested groups by rotasonic drilling methods. The core collected during the drilling will provide additional constraints to the physics of the problem that may provide additional help in redefining the conceptual model. The problem is non-unique with respect to the leakage area and accretion rate and further research is being performed to provide some idea of the advective flow paths using a combination of tritium and ^{3}He analyses and geochemistry. The outcomes of the research will result in a set of benchmark data and physical infrastructure that can be used to evaluate other environmental tracers and modeling techniques.

URL: http://web.utk.edu/~rgentry/research/research.html

H51C-06 1045h

Inverse Modeling to Quantify Recharge in Unconfined Aquifers

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There are several approaches to quantifying recharge, or water-table accretion, in unconfined aquifers. Quantitative approaches include analyzing baseflow recession, estimating flow through the unsaturated zone using tracer studies or modeling, and modeling water-table response. The last of these approaches requires temporal monitoring of the water-table response and, in many cases, requires that transient inverse models be solved for the unknown time-varying recharge function.