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Cumulative watershed effects (CWEs) result from multiple activities over time and space. The assessment of CWEs in the Sierra Nevada is severely limited by the lack of field data on the effects of a given action, the lack of models to predict the effects of multiple actions at the watershed scale, and the limited data relating stream channel conditions to measured or predicted changes in sediment yields. Since 1999 we have been measuring hillslope-scale sediment production rates from roads, timber harvest, wildfires, and minimally-disturbed areas. From these and other data we are developing models to predict sediment production rates from different land uses. The next, more difficult step in developing a reliable CWE model is to compare predicted changes in catchment-scale sediment production rates to stream channel conditions. Channel conditions were measured in 28 pool-riffle reaches in the American and Cosumnes river basins. Contributing areas ranged from 2.9 to 70 km2, and the elevations of the reaches ranged from 1200 to 1800 m. The basins were selected to encompass a wide range in the amount of natural and anthropogenic disturbance. Variables used to characterize the amount of disturbance include road density, number of road crossings, modeled road sediment production, percent forest harvest, and the percent burned by wildfire. The data collected in each reach included gradient, channel dimensions, grain size, amount of large woody debris, and pool size and sediment infill. Preliminary results indicate that basins with more than 20% of the area in granitic lithologies have significantly more fine sediment coverage in pools ($r2=0.35$; $p=0.0002$). The fine sediment coverage in pools also was correlated with the amount of large woody debris. After removing the variability due to lithology and basin area, there was a significant, positive correlation between the estimated sediment production from unpaved roads and residual pool infill volume ($r2=0.14$; $p=0.02$). Other than these relationships, there appear to be no significant correlations between the measured channel characteristics and the amount of disturbance. The limited number of significant correlations may be a consequence of a record flood event in early 1997. This event may have effectively "reset" the stream channels, resulting in a lower detectability of cumulative watershed effects.

H32F-04 1440h

Sedimentation in Pacific Northwest Coastal Streams – Evidence from Regional Surveys of Bed Substrate Size and Stability

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We examined evidence of anthropogenic sedimentation in Oregon and Washington coastal streams using relatively rapid measurements taken from surveys during summer low flows (probability sample, n= 104 reaches). We inferred bankfull channel dimensions from evidence at low flow and compared bed substrate geometric mean diameter (Dgm) with critical diameter (D*cbf) calculated from estimated bed shear stress at bankfull flow stage. We derived an index of Relative Bed Stability, RBS* = Dgm / D*cbf , based on a modified Shield's criterion for incipient motion that includes adjustments to bed shear stress for energy dissipated by large wood and channel irregularities. D*cbf averaged 56 percent of unadjusted values, and Dgm ranged from silt to boulder size. Log10[RBS*] in streams relatively undisturbed by humans was generally between -0.7 and +0.5, showing approximate balance between observed and mobile substrates, but declined to low values (-1.5 to -3.0) in streams with substantial riparian and basin disturbances. Streams draining soft sedimentary lithology showed greater apparent response to these disturbances than did those draining hard basalt lithology. The association of low RBS* with land disturbance, and the stronger absolute values of correlation of Dgm (negative) than D*cbf (zero or positive) with land disturbance in this region strongly suggest that activities including road building, land-clearing, logging and agriculture have augmented sediment supplies and increased fine sediments in stream beds.

H32F-05 1455h

Morphological Effects of Channel Confinement and Riparian Vegetation on Urban and Non-urban Streams of the Pacific Northwest

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The morphological influences of the near-riparian zone on channel morphology and channel responsiveness to urbanization were analyzed in low- and high-urbanized watersheds. Study sites included 22 reaches in a low-urbanized system on the Kitsap Peninsula in western Washington State, paired with 22 reaches having comparable slopes and drainage areas from highly urbanized watersheds in and east of the City of Seattle. Remarkably different channel morphologies were observed between low and high-urbanized reaches. Low-urbanized reaches displayed mainly forced pool-riffle morphology; the high-urbanized reaches were dominated by constrained (armored) step-pool and plane-bed morphologies. In comparison, the low-urbanized reaches had less bank erosion and more in-stream wood, pools, and sediment storage. In low-urbanized watersheds, channel morphology (as quantified by measures of in-stream wood frequency and distribution, pool frequency, sediment storage, and bank erosion) was related to the degree of channel confinement and to characteristics of the near-riparian vegetation. High-urbanized reaches, in contrast, were substantially less sensitive to the condition of the near-riparian zone due to the common stream disconnection with the floodplain triggered by the placement of bank-armoring structures. From a management perspective, an increase in woody debris in plane-bed reaches could yield an eventual morphologic shift to forced pool-riffle. However, increased wood loading in these channels does not guarantee such a shift. These channels also need to be reconnected to their forested floodplain and to the channel-bank sediment, which provide long-term sources of both large woody debris and gravel. In the case of anthropogenically confined channels, restoration is even more challenging because sustainable morphologic improvements would require removal of bank-armoring structures to facilitate that reconnection. The common practice of adding logs results in short-term improvements, but is not likely to provide a sustainable solution in many settings unless equal consideration is given to geomorphic processes that maintain floodplain connectivity.

H32F-06 1510h

Case Studies in Quantification and Mapping of Stream Channel Morphology in the Pacific Northwest: Lessons From Past Efforts and Recommendations for Future Studies, Montana, and Northern California

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Watershed analysis seeks to identify patterns in channel geomorphology and sensitivity of different channel types to management influences. Although most analyses succeed in identifying patterns in the distribution of stream channel morphology and develop reasoned hypotheses regarding effects of past and future management, these conclusions generally rely on extrapolation of trends with high statistical variance. Field data are rarely collected in sufficient quantity and precision to satisfy common standards of statistical rigor. Nevertheless, field data form the basis for conclusions regarding watershed form and process. This paper reviews data from previous analyses in Washington, Montana, and northern California to gain insights regarding limitations on collection of data sets for rigorous analyses, including both high statistical variance in fluvial systems and cost of field surveys. Recommendations for techniques and protocols to develop rigorous field data sets that can be combined with remote sensing data to produce improved watershed scale assessments are offered. These methods are suitable for developing monitoring baseline surveys, which can be utilized for either long-term monitoring and adaptive management experiments.

H32F-07 1525h INVITED

Regression Models That Relate Streams to Watersheds: Coping With Numerous, Collinear Predictors

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GIS efforts can produce a very large number of watershed variables (climate, land use/land cover and topography, all defined for multiple areas of influence) that could serve as candidate predictors in a regression model of reach-scale stream features. Invariably, many of these candidate predictors are correlated with each other, leading to ambiguities in regression model choice, prediction and interpretation. Strategies for coping with collinearity and model choice are illustrated, using watershed and stream data collected from the Willamette Basin in Oregon. Collinearity can greatly inhibit one's ability to determine the relative importance of individual predictors. Sometimes it is easier and clearer to assess the relative importance of groups of conceptually-similar predictors (for example, "natural-gradient" versus "human disturbance" predictors). In addition, one can estimate the amount of model-explained variance in a response variable that is shared by multiple predictors and hence cannot be disentangled. Finally, if multiple, collinear variables are considered as candidate predictors, then model development will likely yield several "best" models, all of them believable and all of them nearly equal in their quality of fit. In this case, one can carry out model averaging of predictions, of relative importance measures, or of the effects of an individual predictor.

H32G MCC: 3024 Wednesday 1600h

Environmental Impacts of Coal-Bed Methane Development I *(joint with B, GC)*

Presiding: **R W Healy,** U.S. Geological Survey**; R L Smith,** U.S. Geological Survey

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H32G-01 1600h

Montana's Coalbed Methane Ground-Water Monitoring Program: Year One

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Tertiary coal seams in the Powder River Basin in southeastern Montana provide three very important resources: ground water, coal, and natural gas. Ground water from springs and wells is essential for the local agricultural economy. Because coal seams in the Fort Union Formation have higher hydraulic conductivity values and are more continuous than the sandstone units, they are the primary aquifers in this region. Coalbed methane (CBM) production is beginning in the Powder River Basin, and requires removal and management of large quantities of water from the coal-seam aquifers. The extensive pumping required to produce the methane is expected to create broad areas of severe potentiometric decline. The Montana CBM ground-water monitoring program, now in place, is based on scientific concepts developed during more than 30 years of coal-mine hydrogeology research. The program includes inventories of ground-water resources and regular monitoring at dedicated wells and selected springs. The program is now providing baseline potentiometric and water-quality data, and will continue to be active through the duration of CBM production and post-production ground-water recovery. An extensive inventory of ground-water resources in the Montana portion of the Powder River Basin has located 300 springs and 21 wells on private land, and 460 springs and 21 wells on U. S. Forest Service and U. S. Bureau of Land Management land, all producing ground water from the methane bearing strata. In southeastern Montana, 134 monitoring wells are currently included in the CBM monitoring program. They are completed either in coal seams, adjacent sandstone units,

or alluvium. During the coal boom of the 1970's and 1980's many monitoring wells were drilled, but most have been since unused. Thirty-six of these existing wells have now been returned to service to decrease start-up costs for the CBM program. This network of existing wells has been augmented at key sites with 26 new wells drilled specifically for the CBM program and 72 existing wells from the coal-mine hydrogeology program. Additionally, drilling of about 25 more wells is in the planning stage. About 20 springs are being monitored specific to CBM. At all sites both water-quantity data (regular water levels, one-time aquifer testing, flow rates at springs) and water-quality data (field parameters or laboratory samples for major and minor constituents) are being collected. Monitoring locations and specific monitoring activities will continue to be adjusted in response to CBM development and data needs. All data collected as part of this program are made immediately available to the public on the Internet through the Montana Ground-Water Information Center (http://mbmggwic.mtech.edu/). Interpretive reports based on data collected will be published under standard scientific protocols. Data and reports will be used by industry, landowners, regulators and researchers in assessing impacts, lack of impacts and recovery of ground-water systems in relation to production of coalbed methane. Funding for this program has been provided by the U. S. Bureau of Land Management, U. S. Forest Service, U. S. Environmental Protection Agency, local Conservation Districts and the State of Montana. Coalbed methane production and consequent impacts to ground-water in this semi-arid region are controversial. Acceptance by all parties of data and interpretations resulting from the CBM monitoring program is enhanced by the credibility established through the more than 30-year history of the coal-mine hydrogeology program.

H32G-02 1615h

Overview of Coal Bed Methane Best Management Practices and Mitigation Techniques Using Geospatial Techniques

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During the second half of the 1990's, Coalbed Methane (CBM) production increased dramatically nationwide to represent a significant new source of income and natural gas for many independent and established producers. Matching these soaring production rates during this period were advancements in Geographical Information System (GIS) technologies generating terra-bytes of new data for the oil & gas industry. Coupled to these accelerating initiatives are many environmental concerns relating to produced water management and impacts to surface and groundwater resources. It is these concerns that have prompted the conceptualization of research sponsored by the U.S. DOE for the development of Best Management Practices (BMP) and mitigation strategies utilizing GIS technologies for efficient environmental protection in conjunction with effective production of coal bed methane. This has been accomplished by developing a framework to take advantage of a combination of investigative field research joined with leading edge GIS technologies for the creation of environmentally characterized regions of study. This paper will provide a summary of coal bed methane best management practices and mitigation strategies as well as the use of an Internet-Based GIS application for geospatial analysis relative coal bed methane development and evaluation of various mitigation techniques and best management practices. Case studies from various basins will be presented and discussed. An update regarding current activities pertaining to ongoing developments of best practices, including produced water beneficial use alternatives, for coal bed methane nationally will be discussed.

URL: http://www.all-llc.com/cbm

H32G-03 1630h INVITED

Iodine-129 and Chlorine-36 as Tracers of Hydrodynamic Processes in Coalbed Methane Systems: Environmental Implications

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Models which predict the response of coalbed methane systems to commercial exploitation generally assume that the coals host groundwaters which belong to a dynamic through-flowing system. For this to occur, fluid migration must be focused along localized fractures and cleat structures. This situation can facilitate enhanced methane recovery through carbon dioxide reinjection, but may also lead to premature breakthrough of the injected gasses to production wells, thereby leaving stranded resources behind in the reservoir. Water encroachment from surrounding areas may also occur and create problems. The emerging alternative view of coal-hosted hydrodynamic systems is that they are essentially static systems which host connate formation waters. Fluid migration is precluded by the presence of gas and its influence on relative permeability in the fractures and cleats. While the removal of these waters will produce local drawdown and allow production of the adsorbed methane, it also represents extraction of a limited and non-renewable hydrologic resource. Understanding which of these hydrodynamic environments is present is critical if informed decisions regarding resource development and exploitation are to be made. We used the ^{129}I and ^{36}Cl systems as indicators of the migration history of fluids in the Fruitland Formation coals in the San Juan Basin of Colorado and New Mexico. Because of their long half-lives (15.7 Myr and 0.3 Myr respectively) these cosmogenic isotopes provide useful constraints on the processes which have occurred since the peat deposits were buried 73 million years ago, and can provide direct evidence on the validity of hydrodynamic models. Our results indicate several isotopically distinct sets of waters are apparent within coals of the Fruitland Formation. The infiltration of recent surface waters is clearly limited to the uplifted basin margins, indicated by the similarity of ^{129}I/I ratios, ^{36}Cl/Cl ratios, δD, and δ^{18}O signatures to those of local rivers and lakes. The rest of the basin is characterized by connate formation waters, some of which were modified by infiltration of groundwaters at the time of Laramide uplift. Isotopic characterization of the source and migration of waters within coalbed systems provides a promising avenue for determining if and how a resource should be developed. Further research is needed to determine the response of environmental isotopes to drilling and gas production.

H32G-04 1645h

Organic and Inorganic Species in CBM Produced Water: Implications for Water Management Strategies

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Coal-bed methane (CBM) wells currently produce close to one billion bbl of water annually and deliver about 8% of total natural gas in the USA. The salinity of this produced water generally is lower than that of water from conventional petroleum wells; salinity commonly is 1,000-20,000 mg/L, but ranges from 200 to 150,000 mg/L TDS. Most CBM wells produce Na-HCO3-Cl type water that is low in trace metals and has no reported NORMs. This water generally has no oil and grease and has relatively low (2-10 mg/L) dissolved organic carbon (DOC), but its organic composition has not been characterized in detail. The water is disposed of by injection into saline aquifers, through evaporation and/or percolation in disposal pits, road spreading, and surface discharge. Water that has low (<1,000 mg/L TDS) salinity and sodium adsorption ratio (SAR) is considered acceptable for irrigation, surface discharge and for injection into freshwater aquifers. Because groundwater associated with coal, especially with lignite and subbituminous coal, is known to contain a variety of toxic or potentially toxic organics, including hydroxyphenols and PAHs, the organic and inorganic compositions of CBM waters should be systematically characterized and their potential for harm to human health, crops and the environment carefully evaluated prior to its addition to existing water supplies. As an alternative to costly disposal, lower salinity produced water from high-yield CBM wells is being considered for reclamation. The treated water would be a valuable new water resource, especially in the arid western USA. The feasibility and cost of reclaiming produced water to meet irrigation, industrial and drinking water standards was evaluated in a 10 gpm pilot field study. The estimated treatment cost was high at about $0.39/bbl$($3,000/acre-ft) for potable water, but would be substantially lower and competitive for irrigation and industrial uses in some arid regions of the USA.

H32G-05 1700h

Organic Compounds in Produced Waters From Coalbed Methane Wells in the Powder River Basin, WY

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Coalbed methane (CBM) is a significant energy resource, accounting for about 7.5% of natural gas production in the USA. The Powder River Basin (PRB), WY is currently one of the most active CBM drilling sites in the USA. One aspect of concern in the exploitation of CBM resources is the large volumes of water recovered from wells along with the natural gas (so-called produced waters). CBM produced waters may contain coal-derived dissolved substances (inorganic and organic) of environmental concern, and a potential disposal problem for CBM producers. Studies of CBM produced water have mostly focused on inorganics. Dissolved organic compounds in CBM produced water may also present an environmental issue, but little information is available. As part of a larger study of the health and environmental effects of organic compounds derived from coal, we analyzed a number of produced water samples from CBM wells in the PRB, WY for dissolved organic substances. Our goals were to: (1) create an initial dataset on organic compounds in produced waters, and (2) integrate these results with our existing results on coal-derived organic compounds in the environment to evaluate potential health and environmental impacts. In 2001, we sampled produced water from 13 CBM wells covering a broad area of the PRB in order to identify and quantify the organic compounds present. In 2002, produced water from 4 of the 2001 CBM wells and 8 new CBM wells were sampled for dissolved organic components. Produced water was collected directly from each well and filtered on site. Organic compounds were isolated from produced water samples by liquid/liquid extraction with methylene chloride and identified and quantified by gas chromatography/mass spectrometry (GC/MS). Organic compounds identified by GC/MS in extracts of the produced water samples, included: phenols, biphenyls, N-, O-, and S-containing heterocyclic compounds, polycyclic aromatic hydrocarbons, phthalates, aliphatic hydrocarbons, and fatty acids. However, most compounds had structures unidentified by GC/MS databases. Many of the identified organic compounds (phenols, heterocyclic compounds, polycyclic aromatic hydrocarbons) are likely coal-derived. Concentrations of individual compounds ranged from about 10 to 0.01 μg/l. Some CBM wells with high concentrations of dissolved organic compounds present in 2001 had much lower concentrations in 2002, indicating temporal variability. Some of the organic compounds identified in the produced water samples are toxic (mutagenic and cancer promoters), but are unlikely to have acute health effects at the low levels present. Chronic health and environmental effects from long periods of low-level exposure, however, are possible. Continuing studies will expand the existing dataset on dissolved organic compounds in produced water, and evaluate the toxic effects of these compounds.

H32G-06 1715h

The Effect of Biogeochemical and Hydrologic Processes on Nitrogen in Stream Water Originating From Coal-Bed Methane Supply Wells

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Water obtained from coal-bed methane (CBM) wells typically contains a variety of reduced chemical constituents, including methane, metal ions, particulate and dissolved organic carbon, and ammonium. In many locales in Wyoming and Montana, CBM water is disposed via discharge to stream channels and reservoirs. Though it is likely that biogeochemical and hydrologic processes will result in major changes in the chemical composition of these waters with subsequent downstream transport, few studies have actually examined

these water quality changes or their ecological impacts. A field study was conducted in the Powder River Basin, WY to document changes in solute composition within stream channels below discharge points of CBM water. Particular emphasis was placed on nitrogen and nitrogen cycling processes. Concentration ranges in discharge water were: DOC, 200-350 μM; alkalinity, 40-50 meq/L; specific conductance, 3.3-4.0 mS/cm; ammonium, 350-400 μM; and pH, 7.2-7.3. Ammonium concentrations decreased with transport distance via nitrification, with subsequent increases in nitrite and nitrate. Within a single discharge channel, nitrite concentrations increased with travel distance, peaking at $>$100 μM at 100-200 m, but also exhibited a strong diel pattern that was inversely related to incident light. Nitrite production/consumption processes differed significantly within in-stream incubation chambers, depending upon location relative to the CBM discharge point and time of day. In the main channel, subject to several CBM discharge points, diel nitrite concentrations were more constant at a fixed station, but did increase with distance downstream. Main channel total inorganic nitrogen remained relatively constant ($\sim$400 μM N) with distance ($>$5 km), suggesting little net nitrogen removal. The results of this study suggest that CBM discharge can serve as a significant source of dissolved nitrogen to western watersheds, with oxidative processes resulting in nitrate and nitrite concentrations greatly in excess of current drinking water limits.

H32G-07 1730h

Characterizing Hydrologic Properties of Coal Beds From the Powder River Basin, Southeastern Montana, by Analysis of Geophysical Well Logs

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As part of a study designed to evaluate the potential for coal-bed methane development in the Powder River Basin of southeastern Montana, six wells were drilled through Paleocene coal beds of the Fort Union Formation along a 31-km transect within the Tongue River drainage basin. Sets of geophysical logs were recorded in these wells, cores were collected, and a complementary aquifer test was conducted at one site across an isolated 4.6-m thick coal seam. Natural gamma and electrical resistivity logs were highly effective in distinguishing individual coal beds. Sonic velocities computed from full-waveform logs were combined with rock densities determined from cores to estimate aquifer storage and results are in reasonable agreement with the value derived from the aquifer test. Televiewer logs, both acoustic and optical, provided magnetically oriented images of the borehole walls. Inspection of these digital projections and comparison with coal cores infer a face cleat orientation of approximately N33°E, in close alignment with regional lineament patterns and the northeast trend of the nearby Tongue River. Further analysis of these televiewer data reveals two primary sets of shallow-dipping features, presumably bedding planes, that are interspersed throughout the rocks and that strike east-west and north-south. These orthogonal directions are aligned with the principal axes of the contemporary stress field in this physiographic province as inferred from a nearby 1984 earthquake. The aquifer test consisted of pumping one of these wells for nine hours and monitoring water levels in three nearby observation wells. The drawdown ellipse generated during this test delineates a horizontal anisotropy ratio of 2.1, with the principal transmissivity tensor aligned N88°E and oblique to cleat orientation. Thus, interpretation of this aquifer test within the context of local structural and tectonic conditions indicates that transmissivity anisotropy in coals at this site is controlled by bedding configuration and perhaps a mechanical response to contemporary stresses rather than solely by cleat geometry.

H32G-08 1745h

Transmissivity Anisotropy in a Bounded Coal-Bed Aquifer in the Powder River Basin, Southeastern Montana Determined by Aquifer Test Analysis

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Extensive installation of well fields to develop coal-bed methane in the Powder River Basin has resulted in large environmental impacts due to discharge of the co-produced water to drainage channels and reservoirs, and to surface disruptions caused by construction of drill pads and gas and water pipelines. These impacts can be reduced by optimizing well spacing based on knowledge of hydraulic properties and boundaries of the coal bed aquifers, including the commonly observed transmissivity anisotropy oriented with face cleat structure. A multiple-well aquifer test was conducted of a 7.6-m thick coal bed located in southeast Montana to determine the magnitude and orientation of the transmissivity tensor, the storage coefficient, and possible aquifer boundaries. Results of the test appear ideal for determining aquifer anisotropy, as the slopes of the semilog time-drawdown curves are nearly identical and the zero-drawdown intercepts are significantly different. The maximum transmissivity, trending N88° E, is 20 m^2/d and the minimum transmissivity 9 m^2/d, defining an anisotropy ratio of 2.1. The effective or geometric mean transmissivity, the value that would be determined from a single-well test, is 13 m^2/d. The corresponding value of hydraulic conductivity is about 2 m/d, which is somewhat larger than most published values for Powder River Basin coal-bed aquifers. Specific storage of the unit is $4X10^{-6}$/m, which is smaller than most published values for Powder River Basin coal beds. The principal anisotropy tensor direction is not aligned with the face cleats, which is dominantly oriented N33° E, as determined from geophysical well logs, but instead is oriented with another fracture set and with dominant east-west tectonic compression. The aquifer test results also indicate the presence of an impermeable or low-permeability boundary. Image well theory, adapted through scale transformation for application to an anisotropic aquifer, indicates that the boundary is likely located about 400 m to the northeast of the production well, and has a strike to the ENE. Results of this test demonstrate that multiple-well aquifer tests can provide hydrologic information not otherwise available to implement optimum spacing and orientation of coal bed methane development wells.

H32H MCC: 3020 Wednesday 1600h

Ecohydrological and Geochemical Processes at the Hillslope and Watershed Scales II *(joint with B)*

Presiding: **M H Nachabe,** University of South Florida**; M C Boufadel,** Temple University**; B D Newman,** Los Alamos National Laboratory**; D Mackay,** State University of New York at Buffalo

H32H-01 1600h INVITED

Hydrology Role in Sustaining Ecological Functions in the Everglades; an Experimental Approach.

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The Everglades ecosystem, the largest subtropical wetland in the United States, has been historically altered to achieve numerous goals such as flood protection, water supply, restoration, conservation, enhancement of specific emergent vegetation types, maintenance or restoration of landscape habitats, and enhancing waterfowl habitat. This “River of Grass” consists of several topographic landscape features (ridges, sloughs, and tree islands), supports a unique variety of plants and wildlife, and provides water resources for both agricultural and urban needs. The South Florida Water Management District and the US Army Corps of Engineers are currently conducting an integrated large-scale effort to restore this ecosystem to a more natural condition. A major part of the ongoing restoration effort is to re-establish the Everglades hydrology by controlling both flow and marsh water levels. The South Florida Water Management District, in collaboration with the A.R.M. Loxahatchee Wildlife Refuge and researchers from several academic institutions, has modified two existing impoundments to replicate the Everglades landscape. The Loxahatchee Impoundment Landscape Assessment (LILA) is designed to assess the impact of seasonal changes in water level and pulsing on wading bird foraging, the significance of flow for the creation and persistence of ridge and slough topography, and to evaluate techniques for restoring tree islands. This project utilizes a scaled-down version of the Everglades landscape to measure responses of wildlife, tree islands, and ridges and sloughs to hydrologic manipulations. Specifically, this study examines the effects of a highly-pulsed (event) pattern of water discharge on wildlife, ridge and slough, and tree island components of the natural system as compared to effects of sustained discharge. LILA provides the opportunity to quantitatively link hydrologic regimes with biological performance measures in a scientifically sound manner that allows for replication and provides information more rapidly than observational studies in the natural system. The main goal of the research program in LILA is to define hydrologic regimes that sustain a healthy Everglades ecosystem. Results of this research program will contribute to supporting routine water management operations and establishing quantitative targets for the Comprehensive Everglades Restoration Project (CERP) Performance Measures. This research program will help develop and recommend options for hydrologic operation of the Everglades, particularly during flood events, when the flexibility to move water through the system is critical. Our discussion is focused on the effects of sediment transport and water velocities on marsh topography, habitat diversity, and their role in sustaining certain ecological functions in the Everglades.

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Solute Transport and Surface-Subsurface Exchange in the Everglades Characterized by a Tracer Release in Surface Water

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Solute tracer injections into flowing surface water are useful to characterize water velocity, dispersive mixing, and biogeochemical reactions that result from processes such as solute exchange between surface water and sediment porewater. Presently, there are few data or guidelines to understand transport processes in the Everglades. Our tracer study was conducted in central Shark Slough, Everglades National Park (25°38' 31.2" N, 80°43' 20.4" W) at an experimental flume facility. The flume consists of 4 side-by-side channels enclosing wetland vegetation in open-ended flow-ways (3-m by 100-m) that are subject to ambient flow conditions. The injection was conducted in one channel that, at the time of the experiment, had 60-cm of surface water and a typical assemblage of Everglades' slough vegetation, including rooted macrophytes (mainly *Eleocharis sp.*), and a well-developed layer (15-cm) of periphyton-coated vegetation (mainly *Utricularia sp.*) below the water surface. A constant-rate injection of sodium bromide (NaBr) was conducted for 22 hours by dividing the flow between four horizontally oriented soaker hoses that were evenly spaced in the water column. At a distance of 6.8 m downstream of the injection, small-volume (10 to 20-ml) water samples were collected on regular intervals for 48 hrs by withdrawing them by suction from 1/8-inch tubes deployed throughout the water column and in the peat sediment to a depth of 30-cm. Transport was characterized by adjusting the parameters of the USGS model OTIS (One-dimensional Transport with Inflow and Storage). Mean velocity of surface water during the experiment was 0.63 cm/s, longitudinal dispersion was 5 x 10^{-5} m^2/s, and fluid residence times in two storage zones, where local mixing but no appreciable downstream transport occurred, were 1 hr (in periphyton-dominated floating vegetation)and 24 hrs in peat porewater), respectively. We conclude that storage-exchange affects solute transport in the Everglades by decreasing the mean water velocity and increasing the time available for biogeochemical processing of non-conservative solutes.

URL: http://water.usgs.gov/nrp/jharvey/site/index.html

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Observations and Modeling of Soil Water Storage in Variable Saturation Zones

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Variable saturation zones occur in shallow water table environments due to the small storage capacity in the soil profile, or the Soil Water Storage Capacity (SWSC). The SWSC is the depth of water required to raise a shallow water table to the land surface. The

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