the fracture network is essential for the analysis and design of slopes. The method used in this paper is relatively simple with acceptable degree of accuracy, and it shows a significative participation of the fracture analysis as an important tool for solving problems concerning the various stages of the slope stability analysis. Keywords: Structural discontinuities; Slope Stability; Drainage map

H42F-1151 1330h POSTER

Fluid-rock interaction at Las Cañadas aquifer, Tenerife, Canary Islands

R. Marrero[1] (rayco@iter.rcanaria.es)

D. López[2]

N.M. Pérez[1]

[1]Environmental Research Division, ITER, Granadilla, Tenerife, Granadilla 38611, Spain

[2]Department of Geological Scienses,, Ohio University, Athens 45701, United States

Las Cañadas caldera, located at the central part of Tenerife, Canary Islands, is a large volcanic depression (16 × 9 km). The caldera is opened to the sea at the north side and filled by continuous layers of lava flows and fall deposits. These volcanic deposits form a good hydrogeological trap which is the largest ground water reserve of the island. In comparison, the basement of the caldera has low permeability. Numerous galleries (horizontal drains) intercept the Las Cañadas aquifer. During the last century, this aquifer has been overexploited depleting the water table as well as the water quality. The Teide-Pico Viejo volcanic complex is located at the margin of the caldera. The ascent of deep magmatic gases (e.g. CO_2) confers aggressiveness to the waters causing rock dissolution and alteration. The aim of this work is to study water-rock interactions in Las Cañadas aquifer. Chemical diagrams showing the relative composition of Mg, Ca, Na and K as described by Giggenbach (1988) indicate that the waters discharged by the galleries correspond to the process of rock dissolution and evolution towards full rock-fluid equilibrium. The lower contents in Ca and Mg are found in the galleries which reach more deeply the north flank of the Teide Volcano, suggesting mineral precipitation and heating in this zone. Geochemical modeling of fluid-rock interactions using Chiller (Reed and Spycher, 1984) show that the gases discharged at Teide summit cannot generate the water compositions observed at Las Cañadas. These gases represent the separated phase of a condensation process within the volcanic edifice. Modeling of the gas-enriched Las Cañadas waters from the recharge zone with phonolitic rocks from the caldera show that the galleries waters correspond to the dissolution of 1 to 7 g of rock÷liter of water and a relatively shallow circulation. The simulations suggest that waters have not encountered the $\sim 250^{\circ}$C temperature region suggested by the gas geothermometers. This behavior suggests that the heat source in this system is deep as suggested by geophysical studies.

URL: http://iter.es

H42F-1152 1330h POSTER

Geologic Controls on Groundwater Flow and Contaminant Transport in Fractured Bedrock

Jim Warner[1] (925-946-0455; jim.warner@erm.com); Melinda Truskowski[1] (925-946-0455; melinda.truskowski@erm.com); Lawrence Fieber[2] (630-990-0300; lfieber@burnsmcd.com); Glen Ernstmann[2] (630-990-0300; gernst@burnsmcd.com); Dan Tisoncik[3] (847-700-6586; dan.tisoncik@ual.com); Ted Wells[3] (847-700-6322; ted.e.wells@ual.com); Jennifer Stanhope[3] (847-700-6269; jennifer.stanhope@ual.com); Bill Henrich[4] (707-763-1312; bill.henrich@norcal.com)

[1]Environmental Resources Management, 1777 Botelho Drive, Suite 260, Walnut Creek, CA 94598, United States

[2]Burns & McDonnell, 2601 West 22nd Street, Oak Brook, IL 60523, United States

[3]United Airlines, 1200 E. Algonquin Road, Elk Grove Township, IL 60007, United States

[4]Norcal Geophysics, 1350 Industrial Avenue, Suite A, Petaluma, CA 94952, United States

This project involves strategic hydrogeologic investigation and remediation of chlorinated solvents in fractured bedrock and overlying alluvium in Northern California. Primary contaminants include 1,1,1-TCA, 1,1-DCE and 1,1- DCA. The source area includes recoverable DNAPL, with a maximum accumulated thickness of 29 feet in a well, and dissolved concentrations in excess of 500 mg/L. The dissolved plume extends away from the source through an extensive fracture network to a depth of 450 feet. The investigation involved drilling monitoring wells to depths up to 700 feet, borehole geophysics, a seismic reflection survey, and aquifer testing. Optical and acoustic televiewer logging were used to map the fracture network, which is dominated by west, southwest, south, and east dipping features. The seismic reflection survey identified en-echelon, southeast dipping normal faults and antithetic, southwest dipping reverse faults that are generally consistent with the orientation of structures in the nearby San Andreas fault zone. The primary fault strikes are generally parallel to those of the dominant fracture sets. Notable lithologic discontinuities in the Franciscan bedrock were documented across major faults, possibly related to significant vertical and strike-slip offset. The seismic reflection survey provided a useful guide for drilling by predicting areas of higher fracture density. Slug tests and acoustic waveform, conductivity, temperature, and static/dynamic heat pulse flow meter logging were used to establish that flow is primarily through the fractures and conductive portions of the alluvium. These data were used to install an effective multilevel well network, establish a ground water flow pattern that reflects geologic controls and regional gradient, and support remediation evaluations. Remediation evaluations include dissolved phase remediation bench tests, DNAPL recovery, and monitored natural attenuation (MNA). The dissolved phase bench tests are in progress. DNAPL has been periodically recovered from fractured bedrock for two years. DNAPL recovery rates declined over time except immediately following a 5.3 Richter magnitude earthquake, which apparently caused a temporary increase. A pilot test demonstrated that dewatering and applying a vacuum to the well increased the DNAPL recovery rate by approximately 2500 percent over rates prior to pilot testing. The MNA results indicate that abiotic and biotic degradation are active, consistent with the apparent steady state condition of the dissolved plume over two years of monitoring. Based on the results, the remedial strategy for the site includes periodic DNAPL recovery with monitored natural attenuation. This study demonstrates the effective use of combined geologic, geophysical, and hydrologic investigation methods to support remedial planning.

H42G MCC: Level 2 Thursday 1330h

Hillslope Hydrologic Processes: New Directions in Monitoring and Modeling II Posters *(joint with NG)*

Presiding: **J P McNamara,** Boise State University**; N E Peters,** U.S. Geological Survey**; P A Troch,** Hydrology and Quantitative Water Management, Wageningen University

H42G-1153 1330h POSTER

Hydrometric Analysis of the Panola Mountain Research Watershed, Georgia, USA: Linkage Among Rainfall, Watershed Wetness, and Stormflow

Norman E Peters[1] (+1 770 903-9145; nepeters@usgs.gov)

James E Freer[2] (+44 1524 593563; j.freer@lancaster.ac.uk)

Brent T Aulenbach[1] (+1 770 903-9148; btaulenb@usgs.gov)

[1]USGS, 3039 Amwiler Rd., Atlanta, GA 30360-2824, United States

[2]Lancaster University, Environmental Sciences, Lancaster LA1 4YQ, United Kingdom

Relations between stormflow characteristics and soil-moisture content, water-table elevation, and precipitation were evaluated for the 41-ha Panola Mountain Research Watershed (PMRW) for water years 1986 through 2001 to refine the conceptualization of streamflow generation. During the 16-year period, precipitation (<1% snowfall) averaged 1,220 mm and annual water yield averaged 30%, ranging from 16% to 50%. Rainfall was relatively uniform throughout the year. For 759 rainstorms, median stormflow (median duration of 33 h) water yield for all rainstorms was small (2.3%), ranging from 1.8% to 7.6%, with the highest median percentage occurring during the dormant wet winter season, when rainfall replenishes the soil-moisture deficit and recharges ground water. Runoff and stormflow were highly correlated with rainfall; the relation indicates that runoff is generally higher for comparable rainfall during the winter compared to the other seasons, which is consistent with higher moisture deficits and higher evapotranspiration in the other seasons. Stormflow water yield correlates best with storm-period maximum soil-moisture content and with storm-period maximum water-table elevation. Furthermore, the relations are linear above thresholds for the entire period and vary by season. For moderate to large rainstorms, relations among wetness parameters and stormflow water yield are better (less scatter) and more consistent when the watershed is seasonally wet than when it is dry. Soil-moisture content (minimum or maximum) is highly correlated among soil depths and with water-table elevations. Stormflow water yield is linearly related to soil-moisture content at 70 cm above 37% volumetric moisture content, occurring 20% of the time. Maximum water-table elevation is linearly related to maximum soil-moisture content above a threshold, and the soil-moisture threshold increases with upslope position; the soil-moisture threshold for flow to occur at a trench hillslope site is 41%, occurring <0.5% of the time. General relations among streamflow, soil moisture, and water-table response are attributed to variable source areas.

H42G-1154 1330h POSTER

Parameterization and Assessment of a Distributed Hydrologic Model

Erin S Brooks[1] (208-885-6562; broo2789@uidaho.edu)

Jan Boll[1] (208-885-7324; jboll@uidaho.edu)

[1]University of Idaho, Dept. of Bio. and Ag. Eng. JML 81C, Moscow, ID 83844-2060, United States

Verification of distributed hydrologic models is rare due to the lack of spatially detailed field measurements and a common mismatch between the scale at which soil hydraulic properties are measured and the scale of a single modeling unit. In this study two of the most commonly calibrated parameters, soil depth and the vertical distribution of lateral saturated hydraulic conductivity (Ks), were eliminated by a spatially detailed soil characterization and results of a hillslope-scale field experiment. The soil moisture routing (SMR) model, a simple distributed hydrologic model, was modified to represent the dominant hydrologic processes for the Palouse region of northern Idaho. The model was applied to a 2 ha catchment without calibration to measured data. Distributed responses were compared to perched water depth measurements made every 12 hours over a three year period on a 10 x 15 m grid. The modified SMR model simulated the perched water table fluctuations across the catchment during the hydrologically active season remarkably well especially given that one mm of error in the water balance would result in an error of 20 mm in water table depth. Simulations also captured water table fluctuations during a year with high spatial variability of snow accumulation and snowmelt rates at up-slope, mid-slope, and toe-slope positions with Nash-Sutcliffe efficiencies as high as 0.79, 0.70, and 0.52, respectively. In one location in the catchment, consistent over-prediction of perched water table heights indicated a localized recharge zone which was not identified by the soil morphological survey. Our detailed data set with its spatial variability in soil properties and dynamic hydrologic measurements is ideal for verification of distributed hydrologic models. Modeling results in this paper show that the simple GIS-based SMR model is physically sound.

H42G-1155 1330h POSTER

Spatial Dynamics of Soil Moisture at Hillslope and Small Catchment Scales

Lawrence E Band[1] (919-962-3921; lband@email.unc.edu)

Stephen Kenworthy[3] (410-455-8017; stk@umbc.edu)

Christina Tague[2,3] ((619) 594 3230; ctague@mail.sdsu.edu)

David Tenenbaum[1] (919-962-8901; davidten@email.unc.edu)

Peter M Groffman[4] (845 677-7600; groffmanp@ecostudies.org)

[1]University of North Carolina, CB#3220, Chapel Hill, NC 27599, United States

[2]Department of Geography, San Diego State University, San Diego, CA 92182.4493, United States

[3]Baltimore Ecosystem Study, 134 TRC Building UMBC, Baltimore, MD 21227

[4]Institute for Ecosystem Studies, Box AB, Millbrook, NY 12545, United States

We present observations of soil moisture patterns in relation to topography in a small, Mid-Atlantic Piedmont basin over a full annual cycle, including a period of severe drought. We document spatial variation in near surface (upper 6 cm) soil moisture, which has an important influence on soil biogeochemical cycling, at a local (25 m2) scale and examine topographic patterns of plot level soil moisture means and variances at the catchment scale. These field observations were

collected in support of a broader project investigating the role of spatial variation in soil moisture and hydrologic connectivity on the transport and biogeochemical cycling of nitrogen in the watershed. Local mean soil moisture in upland areas closely followed a linear trend with the topographic wetness index. Bottomland mean soil moisture typically remained above this linear trend with topographic wetness index, and bottomland soil moisture variance at the plot level was typically much higher than the variance in the uplands. Local variance of soil moisture was highest under intermediate values of soil moisture, decreasing under both wet and dry conditions. We show that both local mean and variance of near surface soil moisture have important sets of controls on nitrogen cycling and export from the basin, and that the spatial and temporal patterns of these parameters in the bottomland are most closely coupling with the biogeochemical behavior of the stream.

H42G-1156 1330h POSTER

Simplicity from complexity: How lateral soil pipes define clear threshold relations at the hillslope scale

Taro Uchida[1] (+81-75-7536093; uchida-t92rv@nilim.go.jp)

Hilda J Tromp-van Meerveld[2] (+1-541-737-4149; ilja.tromp@orst.edu)

Jeffrey J McDonnell[2] (+1-541-737-8720; jeff.mcdonnell@orst.edu)

[1]Research Center for Disaster Risk Management, National Institute for Land and Infrastructure Management, 1 Asahi, Tsukuba 3050804, Japan

[2]Department of Forest Engineering, Oregon State University, Peavy 215, Corvallis, OR 97331, United States

The importance of lateral pipe flow on runoff generation in hillslopes has been described in many case studies from around the world. However, most pipe flow studies published to date have focused on only a few storms at any given site. Consequently, the overall controls on pipe flow response remain poorly understood. We present an intercomparison of pipe flow response to storm rainfall at four well instrumented sites: Panola (Georgia, USA), Toinotani (Kyoto, Japan), Jozankei (Hokkaido, Japan) and Hakyuchi (Tokyo, Japan). Our objective was to whittle down the complexities of lateral pipe flow on hillslopes by looking for commonality across different hillslopes. Despite the large differences between the study sites in topography, climate, soil type and soil matrix hydraulic conductivity, we found several common pipe flow responses to storm rainfall. Most evident was the highly threshold-like behavior of lateral subsurface stormflow and pipeflow, where despite differences in pedon scale soil properties, all of the hillslopes displayed a clear threshold-like response to storm rainfall. We used the results from the comparison to develop a decision tree to help define the conditions necessary for significant pipe flow (and hence, significant hillslope lateral flow generation) to occur. This decision tree is a useful organizational framework to summarize and organize comparative analyses and may provide a structure for defining the hierarchy of process controls. Our comparative analyses demonstrate the effectiveness of site intercomparison for extracting common controls on complex hillslope processes.

H42G-1157 1330h POSTER

Development of an Air Permeameter for Monitoring Changes in Hydraulic Conductivity of Surface Soils due to Fire: Measurements Made Following the 2003 Aspen Fire in Sabino Canyon, Arizona

Karletta Chief[1] (kchief@hwr.arizona.edu)

Bart Nijssen[1,2] (520 626 1277; nijssen@u.arizona.edu)

Paul A. Ferre[1] (ty@hwr.arizona.edu)

Brenda Ekwurzel[1] (ekwurzel@hwr.arizona.edu)

[1]Department of Hydrology and Water Resources, P.O. Box 210011 The University of Arizona, Tucson, AZ 85721-0011, United States

[2]Department of Civil Engineering and Engineering Mechanics, P.O. Box 210072 The University of Arizona, Tucson, AZ 85721-0072, United States

In the Southwest, severe fires can destroy as much as 90% of the vegetation and litter cover. Exposed, burned soils are highly vulnerable to intense monsoon rains, leading to increases in surface runoff, peak flows, and erosion rates. The Aspen Fire in the Coronado National Forest north of Tucson burned in excess of 80,000 acres and destroyed more than 300 structures. As part of an integrated investigation of the hydrologic impacts of this fire, we have developed an air permeameter to rapidly measure the hydraulic conductivity of burned and unburned soils. Results are shown that demonstrate the ability of the air permeameter to rapidly characterize changes in average permeability and spatial variability of permeability over large areas in rocky terrain.

H42G-1158 1330h POSTER

Using Green and Ampt with Redistribution to Simulate Recharge for Saturated Groundwater Modeling in Support of Surface Water Applications

Charles W Downer (305 224-4264; Chuck_Downer@nps.gov)

National Park Service, South Florida Ecosystem Office 950 N. Krome Avenue 3rd Floor, Homestead, FL 33030, United States

The Gridded Surface Subsurface Hydrologic Analysis Model (GSSHA) employs a one-dimensional finite difference approximation of the head based form of Richards' equation to calculate groundwater recharge for saturated groundwater simulations needed for groundwater/surface water interaction studies. When used to simulate sharp wetting fronts, solution of Richards' equation can be computationally very expensive. This computational cost may not be justified if Richards' equation is being solved merely to provide estimates of groundwater recharge for saturated groundwater simulations. For large problems, the computational cost may preclude the used of automated calibration methods which allow a more complete exploration of the parameter space but may require hundreds of simulations to do so. In addition to the Richards' equation solution the GSSHA model also includes Green and Ampt based infiltration models. These Green and Ampt approaches have historically been used to compute infiltration under Hortonian conditions, where saturated groundwater has little influence on surface water flows. It is hypothesized that the Green and Ampt based method of computing infiltration may prove adequate for computing groundwater recharge for use in saturated groundwater simulations. The GSSHA model is modified to allow the Green and Ampt with Redistribution model of infiltration to provide values of groundwater recharge for saturated groundwater simulations. The formulation results in infiltrated water immediately becoming recharge. The modified model is employed in two studies where groundwater surface water interaction is critical to the prediction of stream flow. In both cases the model is able to produce acceptable results in terms of predicting stream flow. The method appears useful for determining values of groundwater recharge for use with saturated groundwater simulations. The reduced simulation times with the method make the use of automated calibration methods possible.

H42H MCC: 3020 Thursday 1340h

Assessing the Impacts of Vegetation on the Water Balance II *(joint with B)*

Presiding: **B R Scanlon,** University of Texas at Austin**; M A Walvoord,** U.S. Geological Survey

H42H-01 1340h

Effects of Model Resolution on Predictions of Vegetation Health in Water-Limited Ecosystems

Andrew J Guswa[1] (413-585-7000; aguswa@smith.edu)

Michael A Celia[2] (celia@princeton.edu)

Ignacio Rodriguez-Iturbe[2] (irodrigu@princeton.edu)

[1]Picker Engineering Program, Smith College, Northampton, MA 01063, United States

[2]Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ 08544, United States

Water-limited ecosystems are characterized by precipitation with low annual totals and significant temporal variability, transpiration that is limited by soil-moisture availability rather than atmospheric demand, and infiltration events that may only partially rewet the vegetation root zone. Average transpiration in such environments is controlled by precipitation, and accurate predictions of vegetation health require an adequate representation of the temporal variation in the timing and intensity of plant uptake. Complexities introduced by variability in depth of infiltration, distribution of roots, and a plant's ability to compensate for spatially heterogeneous soil moisture suggest a minimum vertical resolution required for a satisfactory representation of plant behavior. To explore the effect of model resolution on predictions of vegetation health, we conduct a series of numerical experiments, comparing the results from models of varying resolution for a range of plant and climate conditions. Plant uptake is represented with a Type I model, in which flow through the soil-atmosphere-plant continuum is driven by a potential difference across a network of resistances. To isolate the effects of spatial variations in soil-moisture and uptake, infiltration is simplified to occur instantaneously in response to intermittent storms arriving as a Poisson process. From temporal and spatial scales of the underlying processes and desired output, we develop a dimensionless parameter that indicates the adequacy of a finite-resolution model with respect to reproducing characteristics of plant transpiration over multiple growing seasons. This parameter may be used to determine the spatial resolution required to predict vegetation health in water-limited ecosystems accurately.

H42H-02 1355h

Functional Relationship to Describe Temporal Statistics of Soil Moisture Averaged Over Different Depths

Michael J Puma[1] (917-306-2054; mpuma@princeton.edu)

Michael A Celia[1] (609-258-5425; celia@princeton.edu)

Ignacio Rodriguez-Iturbe[1] (609-258-2287; irodrigu@princeton.edu)

Andrew J Guswa[2] (413-585-7019; aguswa@smith.edu)

[1]Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ 08544, United States

[2]Picker Engineering Program, Smith College, Northampton, MA 01063, United States

Remote sensing techniques typically provide estimates of soil moisture for the top 5 cm of the soil column. Most plants have roots that extend deeper than 5 cm, where the roots interact with soil water to influence processes such as transpiration, CO_2 assimilation, and biomass production. Consequently, soil moisture deeper than 5 cm is an essential component of the soil, plant, and climate system. Detailed simulation studies, highly resolved in space and time, show that a physically controlled relationship exists among instantaneous soil moisture integrated through different soil depths. This dynamic relationship evolves in time as a function of the hydrologic inputs and soil and vegetation characteristics. When soil moisture is calculated at coarser time intervals, such as daily, the structure of the relationship breaks down and becomes undetectable. Since practical measurements tend to be performed at daily intervals or longer, the structure seen at highly resolved temporal scales cannot be captured. If statistical measures are used instead of instantaneous values, the limitation of measurement frequency can be overcome and predictions of mean and variance for variables like soil moisture can be defined over any soil averaging depth d. Then the measured (d=5 cm) mean and variance can be related to the mean and variance of soil moisture over any averaging depth d. For a water-limited ecosystem, we use a detailed simulation model to compute mean and variance for soil moisture over a number of growing seasons, driven by stochastic rainfall forcing over a range of climate conditions, with the mean and variance calculated for different soil averaging depths d. Based on these results, we generate curves that relate the temporal mean and variance of daily-averaged saturation for different averaging depths. These curves are smooth and well behaved, indicating that relationships between soil moisture statistics for different averaging depths exist for the systems under consideration. We seek a predictive framework that relates these curves to dimensionless parameters characterizing the soil, plant, and climate system.

H42H-03 1410h

The Radiative and Hydrologic Response of Tropical Areas to Local Deforestation

David W Werth[1] (919-660-5462; werth@duke.edu)

Roni Avissar[1] (919-660-5200; avissar@duke.edu)

[1]Duke University, Dept. of Civil and Environmental Engineering Box 90287, Durham, NC 27708-0287, United States

The local effects of Tropical deforestation have been modeled at both global and regional scales. The consequent climate changes, most notably a reduction in the precipitation and evaporation, have been explained with a simplified model in which a change to the surface albedo leads to reduction in the net radiant energy absorbed in the overlying column. This leads to a

H