H23D CC: 220 C-E Tuesday 1330h

Groundwater Remediation in Fractured Rock Posters

Presiding: **B Kueper,** Queen's University**; K Novakowski,** Queen's University

H23D-01 1330h POSTER

A method to determine the spacing and transmissivity statistics of "conductive" fractures in which the criterion disgtinguishing between conductive and non-conductive fractures is a sliding scale

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The design of clean-up applications for fractured rock strongly depends on the use of appropriate models and field measurements. Implicit in the use of discrete fracture models is that a subset of fractures have been distinguished from the remaining fractures and labelled as "conductive". Where injection tests have been used to measure permeability along boreholes, the dividing line between these two sets of fractures has traditionally been associated with investigators' ability to measure flow. For example, those sections of borehole into which the rate of injection is below the lower limit of measurement are often associated with the set of "non-conductive" fractures, while those sections into which flow can be measured have been assumed to contain at least one of the conductive set. Snow (1970) used this criteria along with the statistics of a set of transmissivity measurements to derive the mean and variance of the transmissvity of the conductive set. More recently, investigators have used this criteria along with a set of transmissivity magnitudes to derive maximum likelihood estimates of the parameters of a conductive fracture transmissivity set having an assumed gamma-distribution. In this study, provided the distribution of fracture transmissivities is strongly positively skewed, this method of distinguishment is shown to be valid, even in the case where the lower limit of flow rate detection is artificially raised above that associated with equipment. This (upward) sliding detection limit is shown to be useful in the creation of a diminishing (in population) subset of fractures with increasing mean transmissivity and decreasing variance. Using the assumption that the log-normal distribution is stable during addition of small numbers of relatively low variance random variables, the log-normal distribution is shown to be a better model of fracture transmissivity than is the gamma distribution.

H23D-02 1330h POSTER

A Semi-Analytical Model to Describe the Effect of Biofilm Development on Solute Diffusion in Low Permeability Rock

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In fractured rock environments, the process of matrix diffusion strongly influences the persistence of groundwater contamination. Biofilm growth, which occurs naturally in fractured rock, can have a significant effect on the solute transport properties of the matrix, and thus the mobility of contaminants in the system. A semi-analytical model that accounts for the presence of a biofilm has been developed from a solution of the advection-dispersion equation for solute transport in radial coordinates. The model is intended to aid in simulating radial diffusion experiments. It describes solute transport by diffusion from a cylindrical reservoir into a layered medium of finite diameter. The model accounts for linear adsorption and decay in each layer, as well as the periodic addition and/or removal of fluid of known solute concentration from the reservoir. The boundary value problem is solved using the Laplace transform method and Crout's method of LU Decomposition, and numerically inverted using the De Hoog algorithm. According to a sensitivity analysis, compared to the no-biofilm case, diffusion of conservative tracers is most sensitive to the depth of penetration of the biofilm into the matrix, as well as the effective porosity and diffusion coefficient of that penetrated zone. The model developed in this study has been used to interpret the results of diffusion experiments undertaken to investigate mass transport into intact rock samples in the presence of a biofilm and to assign average mass transport parameters to the system. Laboratory data demonstrates that the presence of a biofilm acts to limit diffusive transfer between a discrete fracture and the matrix.

H23D-03 1330h POSTER

Semi-analytical Solutions for Solute Transport in Fractured Porous Media Using a Finite Width Strip Source

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In this paper, transient and steady-state analytical solutions are derived to investigate three-dimensional solute transport in a fractured porous medium. The system consists of evenly spaced, parallel discrete fractures, where solute transport in the fracture is governed by advection-dispersion and the matrix diffusion occurs in the adjacent rock matrix. Transverse dispersion, decay in a finite strip source, and aqueous phase decay in the advection-dispersion equation are also included. Solutions are derived using Laplace and Fourier transforms, and inverted by interchanging the order of integration and utilizing a numerical Laplace inversion algorithm. The application of the solutions to an example site consisting of bedded sandstone impacted with trichloroethylene (TCE) demonstrates the significant influence of source width and transverse dispersivity on plume development. Break-through curves for source widths of 15 m or greater exhibit the same shape, but there is considerable variation in break-through curve attributes for source widths between 1 m and 10 m. Source width significantly affects steady-state plume development, where increasing the width from 1 m to 10 m resulted in a three order of magnitude increase in the down-gradient displacement of the 10 mg/L concentration contour. When considering a base case of longitudinal dispersivity equal to 0.3 m and transverse dispersivity equal to 0.03 m, increasing transverse dispersivity to 0.3 m yields a 3 fold reduction in break-through concentration at 100 m down-gradient from the source. Increasing both longitudinal and transverse dispersivity from the base case values to 1.0 m and 0.1 m, respectively, resulted in a 43% reduction in concentration at the same down-gradient location. The application of decay mechanisms significantly influences contaminant impact and can rapidly mitigate long-term back-diffusion processes. To investigate the influence of decay mechanisms, several cases were considered for modest decay half-life values. For the example site, the absence of decay processes resulted in a steady-state concentration of 180 mg/L at a location 100 m down-gradient from the source. Using a source decay half-life of 3 years reduces the impact, with 5 ppb levels achieved at approximately 3600 years. The inclusion of a source decay half-life of 3 years and an aqueous phase decay half-life of 5 years further mitigates the impact, with 5 ppb concentrations achieved at approximately 50 years.

H23D-04 1330h POSTER

A Sensitivity Analysis of Well Capture Zones in Discretely Fractured Rock

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A Discrete Fracture Network (DFN) model was created using FracMan® to assess what input parameters are most influential in determining the aerial and vertical extent of capture at an existing pump-and-treat system in southwestern Ontario. Two separate three-level factorial designs were conducted; the first evaluated the effect of changing bedding plane fracture parameters P32, mean aperture and mean size on area and depth of capture keeping vertical fracture properties at the base case values. The second evaluated the effect of changing vertical fracture parameters P32, mean aperture and termination % on area and depth of capture keeping bedding plane fracture properties at the base case values. Analysis of Variance (ANOVA) tables and significance analysis was carried out for each of the factorial design analyses data. The effects of mean bedding plane fracture aperture and P32, respectively, were found to significantly affect area and depth of capture and accounted for the greatest percentage of variance in mean area and depth of capture for all simulations in the factorial design. In general, as mean bedding plane fracture aperture and P32 increase, the mean area and depth of capture, respectively, decreases. Mean bedding plane fracture size accounted for only a small percentage of the overall variance in mean area and depth of capture. The interaction effects between bedding plane fracture P32 and mean bedding plane fracture aperture, mean bedding plane fracture size and bedding plane fracture P32 and mean bedding plane fracture size and mean bedding plane fracture aperture, respectively, were found to significantly affect capture zone area. The interaction effect between bedding plane fracture P32 and mean bedding plane fracture aperture was also found to significantly affect the depth of capture. Mean vertical fracture aperture and vertical fracture P32, respectively, were found to significantly affect capture zone area and accounted for the greater percentage of variance in mean area of capture for all simulations in the factorial design. Termination % only accounted for a small percentage of the overall variance in mean area of capture. In general, as mean vertical fracture aperture and vertical fracture P32 increase, respectively, the mean area and depth of capture decreases. Neither vertical fracture P32, mean vertical fracture aperture, nor termination % was found to significantly affect depth of capture. However, the interaction effect between vertical fracture P32 and mean vertical fracture aperture was found to significantly affect the depth of capture and accounted for the greatest percentage of variance in mean depth of capture for all simulations in the factorial design. The interaction effect between vertical fracture P32 and mean vertical fracture aperture was also found to significantly affect capture zone area.

H23E CC: 520 C Tuesday 1330h

Groundwater and Climate Change I

Presiding: **D M Allen,** Simon Fraser University**; G van der Kamp,** National Water Research Institute

H

H23E-01 1330h

Groundwater Supported Evapotranspiration within Glaciated Watersheds under Conditions of Climate Change

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We analyze the effects of geology and geomorphology on surface water/groundwater interactions, evapotranspiration, and runoff generation under conditions of long-term climate change. Our analysis uses hydrologic data from the glaciated Crow Wing watershed in central Minnesota, USA, as well as saturated/unsaturated mathematical modeling. Analysis of historical water table (1970-1993) and lake level (1924–2002) records indicate that larger amplitude, longer period fluctuations occur within the upland portions of watersheds due to the response of the aquifer system to climatic fluctuations. Under dust-bowl type climatic conditions, lake and water table levels fell by as much as 2-4 meters in the uplands but by only a meter in the lowlands. The same pattern can be seen on millennial time scales. Analysis of Holocene lake core records indicate that Moody lake, located near the confluence of the Crow Wing and Mississippi rivers fell by as much as 4 meters between about 4400 and 7000 yr BP. During the same time period, water levels in Lake Mina, located near the watershed divide near Alexandria, MN, fell by about 15 m. These findings are consistent with analytical calculations that indicate that the response time and magnitude of water table and lake level fluctuations will be greatest near the water table divide of large watersheds. A sensitivity analysis was carried out using a transient saturated-unsaturated hydrologic model (HYDRAT2D) to study how aquifer hydraulic conductivity, land surface topography and watershed size can influence watertable fluctuations, westlands formation, evapotranspiration, and runoff. The models were run by recycling relatively wet (1985, 87 cm annual precipitation) climatic record over a period of 10 years followed by 20 years of a dryer (1976, 38 cm precipitation) and warmer climate record. Model results indicated that aquifer-supported evapotranspiration accounted for as much as 12 % (10 cm) of evapotranspiration. The highest hydraulic conductivity aquifers had the least amount of groundwater-supported evapotranspiration owing to deep water tables. Runoff generation due to high water tables was even more sensitive to aquifer conductivity, especially in the lowland regions. Increasing the length scale of the basin resulted in more aquifer-supported evapotranspiration due to the relatively higher water tables produced. These findings have important implications for paleoclimatic studies since the hydrologic response of a surface water body will vary across the watershed to a given climate signal.

H23E-02 1350h INVITED

Groundwater Resources And Climate Change: Trends From Eastern Canada

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Groundwater plays a major role in the water cycle since it is the largest reservoir of fresh water on earth. In Canada, 30 of the population relies on groundwater for their drinking-water supply. In eastern Canada, this percentage reaches 50 to 100, depending on the province. The renewal of this resource and thus the amount of groundwater available for consumption in a specific region is dependant upon climatic conditions, groundwater uses, evapotranspiration and runoff. Climate changes may have an impact on groundwater levels in aquifers, and groundwater availability. Indeed, it is established that an increase in temperature result in an increase in both evaporation and transpiration, which in turn may decrease aquifer recharge. Moreover, changes in precipitation patterns also have a potential impact on recharge, since intense rain events do not infiltrate efficiently. A research project was thus designed to assess the potential impacts of climate change on groundwater in Quebec and the Atlantic Provinces, Canada. The main objective was to understand the relationship between climate and groundwater recharge by using historical data sets of groundwater levels, temperatures, precipitation and stream hydrographs. The database developed for the project includes information from 95 wells, 169 stream gauging stations and 68 meteorological stations reaching close to 7 millions entries. Time series coming from wells that are influenced or not by pumping, cover periods of 15 to 30 years, while climatic and river discharge data are available for up to 100 years. Firstly, base flow calculation were performed on river discharge data using three hydrograph separation methods (one graphical and two using filters). Secondly, a strong relationship was established between base flow time series, which represent the contribution of groundwater to the river system, and groundwater-level fluctuation data from the nearest well. Aquifer recharge values were then estimated at the regional scale for each watershed. Major trends for mean temperatures, total precipitation and annual recharge values were then evaluated both from a simple linear regression calculation and by the Mann-Kendall non-parametric statistical test. From the 169 stream gauging stations, only 15 stations have time-series statistically valid for Québec, New Brunswick and PEI. Results from these locations show that both temperature and precipitation seem to increase since the beginning of the twentieth century, while the annual recharge is either stable or gently decreasing over time. These results provide a preliminary assessment of the impact of climatic factors and anthropogenic activities (greater demand for potable water) on fluctuations of groundwater levels. For eastern Canada, it seems that the groundwater resource is not particularly at risk when one foresees the projections from GCM and compare it with the actual groundwater use, but these trends suggest that the lowering of the groundwater table is likely linked to an increase in evapotranspiration and runoff (which is related to land use and precipitation patterns). Further analysis would provide insights into possible impacts of increased pumping in those regions. Future projections tend to imply that private well owners with shallow wells and small rivers, creeks or humid environments will first be at risk

H23E-03 1410h

Response of Groundwater Recharge to Potential Future Climate Change in the Grand River Watershed

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The Grand River watershed is situated in southwestern Ontario, draining an area of nearly 7000 square kilometres into Lake Erie. Approximately eighty percent of the population in the watershed derive their drinking water from groundwater sources. Quantifying the recharge input to the groundwater system and the impact of climate variability due to climate change is, therefore, essential for ensuring the quantity and sustainability of the watershed's drinking water resources in the future. The primary goal of this study is to investigate the impact of potential future climate changes on groundwater recharge in the Grand River watershed. The physically based hydrologic model HELP3 is used in conjunction with GIS to simulate the past conditions and future changes in evapotranspiration, potential surface runoff, and groundwater recharge rates as a result of projected changes in the regions climate. The climate change projections are based on the general predictions reported by the Intergovernmental Panel on Climate Change (IPCC) in 2001. Forty years of daily historical weather data are used as the reference condition. The impact of climate change on the hydrologic cycle over a forty year study period is modelled by perturbing the HELP3 model input parameters using predicted future changes in precipitation, temperature, and solar radiation. The changes in land use and vegetation cover over time were not considered in the study. The results of the study indicate that the overall simulated rate of groundwater recharge is predicted to increase in the watershed as a result of the projected future climate change. Warmer winter temperatures will reduce the extent and duration of ground frost and shift the springmelt from spring toward winter months, allowing more water to infiltrate into the ground. This results in decreased surface runoff, higher infiltration, and subsequently increased groundwater recharge. The predicted higher intensity and frequency of future precipitation will not only contribute significantly to increased surface runoff, but also results in higher evapotranspiration and groundwater recharge rates due to increased amounts of available water. Changes in the incoming solar radiation have a minimal impact on the simulated hydrologic processes. The overall simulated average annual recharge in the watershed is predicted to increase by approximately 100 mm/year over the next forty years from 189 mm/year to 289 mm/year.

H23E-04 1425h

Linking Climate, Hydrology and Groundwater in High-Resolution Transient Groundwater Flow Models: a Case Study For a Climate Change Impacts Assessment in Grand Forks, BC

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A case study of an unconfined aquifer in the Grand Forks valley in south-central BC was used to develop methodology for linking climate models, hydrologic models, and groundwater models to investigate future impacts of climate change on groundwater resources. A three dimensional groundwater flow model of variable spatial resolution (constrained by borehole spacing) was implemented in MODFLOW, and calibrated to observation well data. Multiple scenarios of the hydraulic conductivity fields were used in a sensitivity analysis. A new methodology was developed for generating spatially-distributed and temporally-varying recharge zonation for the surficial aquifer, using GIS linked to the one-dimensional HELP (USEPA) hydrologic model that estimates aquifer recharge. The recharge model accounts for soil distribution, vadose zone depth and hydraulic conductivity, extent of impermeable areas, surficial geology, and vadose zone thickness. Production well pumping and irrigation return flow during the summer season were included in recharge computations. Although recharge was computed as monthly averages per climate scenario, it is driven by physically-based daily weather inputs generated by a stochastic weather generator and calibrated to local observed climate. Four year long climate scenarios were run, each representing one typical year in the present and future (2020s, 2050s, and 2080s), by perturbing the historical weather according to the downscaled CGCM1 general circulation model results (Environment Canada). CGCM1 model outputs were calibrated for local conditions during the downscaling procedure. These include absolute and relative changes in precipitation; including indirect measures of precipitation intensity, dry and wet spell lengths, temperature, and solar radiation for the evapotranspiration model. CGCM1 downscaling was also used to predict basin-scale runoff for the Kettle River upstream of Grand Forks. This river exerts strong control on the groundwater levels in the aquifer and physically-based discharge predictions were used in the transient groundwater flow model. Modeled discharge hydrographs were converted to river stage hydrographs at each of 123 river segments, and interpolated between known river channel cross-sections. Stage-discharge curves were estimated using the BRANCH model and calibrated to observed historical data. River channels were represented in three-dimensions using a high grid density (14 to 25 m) in MODFLOW, which were mapped onto river segments. River stage schedules along the 26 km long meandering channel were imported at varying, but high, temporal resolution (1 to 5 days) for every cell location independently. Head differences were computed at each time step for historical and future, mapped in GIS and linked to the MODFLOW model. Temporal changes in mass balance components show relations between pumping, storage, recharge, and flow. Within an annual cycle and between climate scenarios the results show different spatial and temporal distributions in groundwater conditions. Groundwater levels near the river floodplain are predicted to be lower earlier in the year under future climate scenarios, but away from rivers, groundwater levels increase slightly due to the predicted increase in recharge.

H23E-05 1440h

Climate change impacts on Chalk groundwater resources in eastern England

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Climate change is expected to cause higher summer temperatures, less summer rainfall and more evapotranspiration in eastern England during this century, thereby increasing the stress on the underlying Chalk aquifer. This study, funded by the Tyndall Centre for Climate Change Research, investigates how future scenarios of climate change will influence groundwater availability in this major regional aquifer in terms of groundwater levels and river baseflow quantities. To examine these scenarios, a two-layer regional groundwater model was constructed with Visual MODFLOW for the Wensum and Nar river catchments in northern East Anglia. The UKCIP02 database for the 2020s High' and 2050s High and Low' gas emission scenarios was used to define selected future climate conditions. Historic recharge (1981-90) to the model is calculated separately, using the FAO approved method incorporating dominant land cover (crop type) and soil moisture content. Future recharge to the model is estimated by perturbing historic rainfall and evapotranspiration with scaling factors relating average monthly simulated future and baseline (1961-90) meteorological parameters. The model results predict an overall decrease in recharge for all three scenarios, with a maximum decrease in October of 62% and 91%, for both the 2020s High and 2050s High scenarios, respectively. The future drier summer periods are likely to cause a delay in the onset of recharge by a month, due to a corresponding

overall increase in the evapotranspiration for all scenarios. Faced with these conditions, water companies are planning for less reliable groundwater resources within an overall risk-based approach to managing future water supply and demand.

H23F CC: 520 A Tuesday 1330h

Advanced Methods for Probabilistic Hydrometeorologic Forecasting III

Presiding: **J Demargne,** NOAA Hydrology Laboratory**; A Pietroniro,** National Hydrology Research Center

H23F-01 1330h

Ensemble streamflow forecasting in snowmelt-dominated river basins

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We are undertaking a detailed study to improve both the accuracy and probabilistic information content of streamflow forecasts in the Colorado River basin. Our two main research objectives are: (1) Development and evaluation of methods to assimilate station-based measurements of snow water equivalent into the NWS River Forecast System; and (2) Development and evaluation of methods to produce forecast inputs on time scales of days through to seasons. For forecast lead times up to two weeks, our experimental forecasting methods have significantly higher skill than the operational methods used by the NWS. On seasonal time scales, our experimental forecasting methods add skill over the operational methods, especially in the lower Colorado River basin where ENSO signals are strong. Further, in specific cases, assimilation of SNOTEL measurements of snow water equivalent are found to improve streamflow forecasts.

H23F-02 1345h

Probabilistic Hydroclimatic Forecasts based on MultiModel Ensembling

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Seasonal forecasts of precipitation/streamflow are essential for the management of water supply systems as well as for developing various strategies of crop management in rain fed agriculture. However, climatic forecasts from different General Circulation Models (GCMs) and statistical models can differ significantly across these models, thereby necessitating the development of methodologies that focus on optimal combination of model ensembles. IRI dynamical climate forecast system pursues such an approach to develop IRI Net Assessment Forecast. In this study, we develop a similar approach to develop multimodel ensembles of streamflow forecasts conditioned on climatic indices. The methodology obtains multimodel streamflow ensembles through an iterative weighting scheme. The performance of the multimodel ensemble is compared with the skill of individual model based approach.

H23F-03 1400h

Towards Operational Probabilistic Quantitative Precipitation Estimation Using NEXRAD

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Large uncertainties associated with the operational quantitative precipitation estimates produced by the U.S. national network of WSR-88D radars known as NEXRAD are well-acknowledged. These uncertainties include both systematic and random effects of numerous sources. Quantitative description of the precipitation estimation errors would help the U.S. National Weather Service (NWS) forecasters in making operational decisions on issuing forecasts and warnings on flooding potential. It would also help the commercial sector and other agencies that use the rainfall products in making risk-based decisions. Currently such information is not available. The authors describe a comprehensive plan of introducing probabilistic quantitative precipitation estimation into the operational NWS environment. The plan focuses on radar-based estimates and includes research and development, experimental, and implementation components. The authors discuss three different possible approaches with their merits and problems. They recommend one of the approaches based on a parameterization of radar-rainfall errors taking into account space and time scale, range, seasonal, synoptic and climatic dependencies. They discuss details of the resources required and the implementation feasibility.

H23F-04 1415h

Wavelet-Based Evaluation of Rainfall-Runoff Models

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Objective functions (e.g. the Nash-Sutcliffe efficiency index) are crucial to the inter-comparison of rainfall-runoff models with different process representations and parameterisations. They are also routinely used as the target of model optimisation and as the parameters used to describe model uncertainty under different parameter sets. The problems of objective functions are well-established, as individual functions may require one or more of: (a) a mean error of zero; (b) a distribution of error that is Gaussian (either before or after some form of transformation); (c) an error series that is not autocorrelated; and (d) an error series that is homoscedastic (i.e. the variance of the error does not change as a function of time). Unfortunately, there are good reasons why these four requirements do not hold. This largely relates to the fact that hydrological processes are influenced by a number of scales of variation (from the storm event through to seasonal variation in soil moisture conditions). The associated error series therefore integrates errors due to a range of time scales and magnitudes of variability (e.g. high magnitude, short duration error in the prediction of a flood peak will be superimposed upon low magnitude, long duration error due to inadequate evapotranspiration treatment). These errors will also be inter-correlated (i.e. the magnitude of flood peak error will depend upon the magnitude of evapotranspiration error). In this paper, a method for addressing this problem is developed and evaluated. This is based upon disaggregation of the error series using a time-frequency localisation based upon wavelet analysis. Wavelet analysis measures the fit of a data series to a wavelet basis function with a range of scales and at all time periods. Thus, it yields the characteristic time scale of a phenomenon present in a data series at all time periods. This paper develops and evaluates a continuous wavelet transform for disaggregating observed runoff data and predictions from a modified form of the classical TOPMODEL. Use of the cross-wavelet spectrum and phase coherence allows explicit identification of when model predictions diverge from observations and the associated time scale over which this occurs. The paper shows that such divergence can be hidden by more conventional objective functions and so provides an additional explanation of possible causes of model equifinality.

H23F-05 1430h

Appraisal of Forecast Value for Groundwater Resources Management

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Seasonal climate forecasts present an opportunity to increase the efficiency with which water resources are managed. However, the probabilistic nature of forecasts poses challenges to potential users and complicates evaluation of the forecasts' quality and value. In this study we use Bayesian decision modeling to evaluate the performance of a seasonal precipitation forecast. We generate an optimal decision map by which probabilistic categorical forecasts are re-categorized and evaluated. In this way, forecast performance is assessed not in terms of the observed climate state but rather in terms of the decision indicated by the forecast. Preposterior analysis via stochastic dynamic programming is used to determine the expected value of the forecast. The application setting is the Palar River basin in Tamil Nadu, India, where demand for water exceeds economically available resources leading to income loss, economic displacement and environmental degradation. Instead of targeting forecasts for use by farmers, we propose that water managers use forecasts to set economic parameters to signal the expected availability of water in the coming season. The economic signal promotes efficient use of water while mitigating the farmers' personal risk of forecast-based decisions.

H23F-06 1445h INVITED

Seasonal to Interannual Hydroclimatic Prediction: From Identification of Dynamics to Multi-Attribute Forecasts

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Dynamical and Statistical Models for seasonal to interannual forecasts of key hydroclimatic state variables have been explored in recent years. Many authors report success based on typical performance metrics. Thus, a casual external observer may feel that we are at the verge of a breakthrough in hydrologic prediction, and hence in water resource management. This talk explores this notion, with particular regard to the multi-scale (time and space) nature of hydrologic fluxes, and of the management variables and styles that the water resources community has become accustomed to. A conceptual framework for the nascent predictive science of hydroclimatology is developed and exemplified. Aspects of the dynamics that need to be understood, and a unifying estimation/inference framework are proposed.

H24A CC: 520 C Tuesday 1530h

Coupling Microbial Activity, Water Flow, and Solute Transport in the Subsurface I *(joint with B)*

Presiding: **J E Smith,** McMaster University**; M Rockhold,** Pacific Northwest National Laboratory

H24A-01 1530h

Effects of Diffusion Fragmentation and Spatial Constraints on Soil Microbial Diversity

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Evidences show unparalleled microbial diversity at very small scale in soils as compared with aquatic habitats (oceans) - soils contain numerous genotypes per unit volume. Yet the causes of such abundance remain largely unknown due to our limited understanding of relationship between soil microbes and their environment and interaction among microbial populations. We developed a conceptual model for the role of habitat heterogeneity, induced by physical constraints and fragmentation of diffusion pathways on abundance and coexistence among microbial genotypes. The model simulates competition between two microbial cultures with different key growth and diffusion (motility) properties within a soil domain. Diffusion-reaction equation is used to simulate nutrient capture, growth and spreading of the microbial population. Spatial constraints according to soil pore sizes are introduced to limit maximum microbial volume within a specific soil volume. In the absence of spatial constraints, only one of the