A few recent drought years are selected for analyzing of the dynamical structures of the regional circulation patterns and the tropical ocean and global atmosphere. These tended to coincide with El Ninos. However, the selected years include the recent drought during the 2001/2002 rainfall season, which occurred in a neutral El Nino-Southern Oscillation (ENSO) phase. There emerged significant similarity between rainfall anomaly variability and the ENSO signals. The many parameters of the atmosphere showed consistent characteristics in different drought years. The regional circulation patterns associated with droughts show similarities in both active and neutral ENSO years.

The study also shows how possible generators of the climate anomalies can be grouped together. Thus the diagnosis of the various fields contributes to developing a framework for providing skilful predictive tools in order to minimize the vulnerability of the region to the extremes in the variation of the climate system.

H71D-0831 0830h POSTER

An Examination of the Spatial and Temporal Patterns of Agricultural Drought in the Canadian Prairies

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Palmer's Moisture Anomaly Index (Z-index) was used to characterize the frequency, severity, and spatial extent of growing season agricultural drought events for 43 crop districts across the Canadian prairies during 1920-1999. The crop districts were divided into five relatively homogeneous regions based on a cluster analysis of the Z-index values. Drought statistics were calculated and analysed for each of the drought regions. The single most severe growing season drought on the Canadian prairies occurred in 1961. This drought covered more than 86% of the study region and had a mean severity (Z-index) of -5.67. Other severe growing season droughts occurred in the Canadian prairies (in order of severity) in 1988, 1929, and 1937. The results demonstrated that the severity and spatial extent of droughts on the Canadian prairies are strongly correlated indicating that more severe drought events tend to affect larger areas. The most drought prone crop districts experienced moisture conditions unsuitable for crop production approximately one out every six growing seasons. The spatial analysis revealed the existence of several preferred spatial patterns of drought. The temporal analysis verified the presence of coherent drought periodicities (in particular quasi-2, 4, and 10-15 year oscillations).

H71D-0832 0830h POSTER

Hydroclimatic Variations and the Spatial Scales of Drought Severity in the Interior Western United States

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In the semi-arid interior west, watershed health and drought severity depend on the overlapping scales of climatic variations (and associated snow, temperature, warm season precipitation anomalies), vegetation stress, and streamflow volumes. Consequently, diagnosis and assessment of drought must account for these hydroclimatic and ecological indices and their year-to-year variations. Based on historical streamflow records, high-resolution vegetation indices, and climate data, we investigate the spatiotemporal variations in runoff efficiency and drought probabilities. The proposed framework provides a fresh perspective on drought characterization, monitoring, and prediction for water resources management, drought planning, fire risk, and resource allocation.

H71D-0833 0830h POSTER

An Aggregate Drought Index (ADI) to Quantify Drought Severity Across Multiple Time Scales

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A multivariate, principal-component based index is introduced to quantify the severity of droughts. The Aggregate Drought Index (ADI) describes the meteorological, hydrological, and agricultural aspects of drought on a climate-divisional basis, using fluctuations in the values of five variables associated with the hydrologic cycle and available water: precipitation, evaporation, streamflow, reservoir storage, and soil moisture. Additionally, the ADI considers the snow water content of snowpack reserves (for months and regions where appropriate). The ADI is computed as the first principal component of the observational dataset, where the principal components are determined using a correlation-based approach. Index computations are performed separately for each of the twelve months, such that the signal is not biased by the differing hydroclimatologies of distinct months. The twelve series are ordered chronologically, and the basic monthly chronology is extended to produce time series of drought across 3, 6, 12, 24, 36, 48, 60, and 72 month periods. Drought severities over multiple time scales are presented for three California climate divisions during the minimum period of 1975-2000. A methodology is also presented for the routine, real-time computation of current ADI values.

H71D-0834 0830h POSTER

A hydrological-climatological-ecological drought severity index

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Droughts are studied either from a pure climatological prespective (precipitation deficit), hydrological perspective (low streamflow) or ecological perspective (low vegetation). This paper intends to study droughts and their occurences using a hydrological model of the soil layers complete with infiltration, runoff, evaporation and temporal evolution of the soil moisture. We propose a new method of integration of precipitation, soil moisture, streamflow, water table and vegetation information into an integrated hydrological-climatological-ecological drought severity index. However, several roadblocks exist for such a coupled index. Water table information (if available) is very sparse and these are influenced by withdrawls. Vegetation data is available via remote sensing and is very seasonal. Precipitation is highly variable in space and has this has to be factored in the index calculation. This paper will provide a framework for such a complex and complete integration.

H71D-0835 0830h POSTER

Analyzing Drought From Paleo-Reconstructions Of 7-Day Low Flow In The Hudson River Basin

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The annual 7-day low flow in a stream is a measure of the dry season conditions in a stream. Consequently, it is a useful indicator for multi-year droughts. Here, we first present the application of a Generalized Linear Model in a Bayesian Hierarchical Modeling Framework for reconstructing the annual 7-day low flow series at 5 locations in the Hudson River Basin using 11 regional tree ring chronologies. This technique directly provides estimates of the posterior probability distribution of each reconstructed streamflow value, considering model parameter uncertainty. Given these reconstructions, we examine the frequency and recurrence attributes of extreme droughts in the region and their potential connections to known low frequency climate modes.

H71D-0836 0830h POSTER

A Local Forecast of Land Surface Wetness Conditions, Drought, and St. Louis Encephalitis Virus Transmission Derived from Seasonal Climate Predictions

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We present an ensemble local hydrologic forecast derived from the seasonal forecasts of the International Research Institute (IRI) for Climate Prediction. Three-month seasonal forecasts were used to resample historical meteorological conditions and generate ensemble forcing datasets for a TOPMODEL-based hydrology model. Eleven retrospective forecasts were run at a Florida and New York site. Forecast skill was assessed for mean area modeled water table depth (WTD), i.e. near surface soil wetness conditions, and compared with WTD simulated with observed data. Hydrology model forecast skill was evident at the Florida site but not at the New York site. At the Florida site, persistence of hydrologic conditions and local skill of the IRI seasonal forecast contributed to the local hydrologic forecast skill. This forecast will permit probabilistic prediction of future hydrologic conditions.

At the Florida site, we have also quantified the link between modeled WTD (i.e. drought) and the amplification and transmission of St. Louis Encephalitis virus (SLEV). We derive an empirical relationship between modeled land surface wetness and levels of SLEV transmission associated with human clinical cases. We then combine the seasonal forecasts of local, modeled WTD with this empirical relationship and produce retrospective probabilistic seasonal forecasts of epidemic SLEV transmission in Florida. Epidemic SLEV transmission forecast skill is demonstrated. These findings will permit real-time forecast of drought and resultant SLEV transmission in Florida.

H71E MCC: 130 Sunday 0830h

Observations and Modeling of Land Surface Hydrological Processes II

(joint with GC)

Presiding: **V Lakshmi,** University of South Carolina**; T Cahill,** Texas AM University

H71E-01 0835h INVITED

Soil Moisture Experiments 2003 (SMEX03)

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A series of large-scale soil moisture field experiments have been conducted over the past decade. These have been successful at addressing a broad range of science question, focusing technology development and demonstration, and providing educational experiences for undergraduate and graduate students. Soil Moisture Experiments 2003 (SMEX03) will focus on satellite based soil moisture products. The NASA Aqua and Japanese ADEOS-II Advanced Microwave Scanning Radiometer (AMSR) Programs are committed to developing and providing daily soil moisture products. This is the first time that this challenging task has

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ever been attempted. The wide range of vegetation conditions that have to be dealt with, due to the global coverage and multi-temporal observations, exceed those that have been evaluated in previous investigations. For these reasons, validation is critical to the AMSR soil moisture product development and acceptance. SMEX03 will provide validation data for a wide range of vegetation conditions ranging from well-understood grass and wheat in Oklahoma to new observations of the Amazon rainforests. In addition it will provide a test bed for other new satellite instruments such as the Envisat ASAR and aircraft based prototype satellite instruments. SMEX03 will be conducted at U.S. sites in Oklahoma, Georgia and Alabama in June and July and Brazil in September.

H71E-02 0855h INVITED

The NASA Working Group on River and Wetland Hydrologic Processes

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A number of important science questions regarding hydrologic processes across rivers and wetlands remain unanswered primarily due to the inability of in-channel gauging stations to characterize spatially varying flow conditions and storage. A key example is the lack of in-situ measurements of water levels across a majority of the worlds floodplains and wetlands. Non-channelized flow conditions across wetlands limit the effectiveness of singular gauging stations for measuring the changes in storage and related discharge. Instead, laterally-spatial measurements are required to characterize these hydrologic processes, rather than cross-sectional point observations. Remote sensing, therefore, should allow observation of floodplain and wetland processes not currently feasible with ground-based measurements. Lacking these observations, questions remain regarding the changes in wetland storage, the global magnitude of biogeochemical fluxes from wetlands, sediment transport between channels and floodplains, flooding hazards, and the role of these processes in the global hydrologic cycle. Fortunately, remote sensing has provided potential avenues toward answering these hydrologic questions. Among the most promising are active radar and lidar methods that measure inundation area, water heights, and changes. The global observations possible from such platforms will have important implications for global water cycle research. Our NASA working group invites participation from everyone interested in solving these questions.

H71E-03 0915h INVITED

Hydrologic Modeling of Snow Dynamics in the U.S., the Problem with Point Observations, and the Need for Improved Remote Sensing of Snow Characteristics

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Hydrological models used in research and operational applications are modest representations of the actual hydrologic system. Whether simple or complex, good models provide reliable guidance, but cannot represent every situation, every process that occurs in nature. Consequently, observations of important hydrologic states are necessary to evaluate model results, and importantly, to make corrections to the model so that it performs better in the future. Unfortunately, hydrologic observing systems have not, in general, kept pace with the rapid advances in hydrologic modeling seen over the past decade. Spatially distributed, physically based models can now be run at high spatial and temporal resolution, greatly reducing the uncertainties associated with model parameterization. Models in this class can provide detailed, apparently realistic information about hydrologic states and processes that simply stretches or exceeds the limits of model evaluation and data assimilation using available observations.

In the U.S., water stored and released from seasonal snow packs directly leads to gross national revenue on the order of hundreds of billions of dollars each year, in the form of hydroelectric power generation, agriculture, manufacturing, recreation, and other activities. Snowmelt flooding is a chronic problem in many areas of the country, resulting in lost lives and several billion dollars in damages every few years. The distribution and state of snow cover affects weather and climate patterns around the globe, with immense but poorly understood consequences. Accurate, reliable snow models are necessary to understand and predict the formation, evolution, and ablation of snow packs and the soil states beneath them that affect snowmelt runoff. The National Operational Hydrologic Remote Sensing Center (National Weather Service, NOAA) is operating a new multi-layer snow/soil model for the continental U.S. at 1-km spatial resolution and hourly temporal resolution, to provide improved snow information to the government, academia, and the public. The model provides an exciting new look at snow pack dynamics across the country, but it is still just a model, and requires appropriate snow observations for evaluation and assimilation to correct model states. The characteristics of snow observations available in the U.S. has proven to be a severe limitation in this regard. The NASA Cold Land Processes Field Experiment, conducted earlier this year, has provided new research data sets that have already helped quantify the problem of using point (ground) observations of snow in spatially distributed snow models. Results indicate that although the snow model operates at high spatial resolution for improved physical representation of processes, assimilation of point observations of snow states is limited to gross regional corrections, where a sufficient number of point observations exist to reveal a pattern of model errors. Analyses of these data underscore the need for advanced remote sensing measurements of process-oriented snow characteristics, at resolutions commensurate with modern hydrologic models, to reliably evaluate and correct the models on a spatially distributed basis.

URL: http://www.nohrsc.nws.gov

H71E-04 0935h

An Optimality Principle of Evaporation Over Non-vegetated Land Surface

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A hypothesis about evaporation and the associated energy fluxes is proposed and tested based on an argument of thermodynamic equilibrium. It is hypothesized that land-atmosphere interactive processes lead to states of surface soil moisture, surface temperature, and heat fluxes into the atmosphere and the soil that maximize evaporation for a given level of energy supply and properties of the soil. General equations have been derived for the surface variables of temperature and soil moisture and the heat fluxes corresponding to the maximum evaporation. An objective evaluaton of the generic equations using the measurements of surface temperature, soil moisture, and the surface heat fluxes from past field experiments yields convincing evidence in support of the optimality principle of evaporation.

H71E-05 0950h

An Analytical Method for Predicting Soil Moisture from Rainfall Observations

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A simple analytical method for estimating soil moisture directly from rainfall data is proposed and studied. The soil moisture dynamics is represented by a linear stochastic partial differential equation (Entekhabi and Rodriguez-Iturbe, 1994). A diagnostic equation is derived from the soil moisture dynamics equation by neglecting the diffusion term. The derived daily soil moisture is a function of time-weighted average of previous cumulative rainfall over a period (e.g., $>$ 14 days). The advantage of this method is that no information of the initial condition of soil moisture is needed. Two coefficients in the diagnostic equation, i.e., the loss coefficient and the ratio of infiltration to rainfall, are found to be correlated with land surface characteristics strongly, especially soil properties. The methodologies for determining the averaging window size, the loss coefficient and the rainfall-infiltration ratio are studied. The soil moisture data observed during three field experiments, i.e., Monsoon90, Washita92, and SGP97 are compared to the derived soil moisture. The results demonstrate that the proposed method is robust and has the potential for soil moisture predictions.

H71E-06 1025h

Ground-Based Soil Moisture Observations Within Satellite Footprints During SMEX02

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The Soil Moisture Experiment 2002 (SMEX02) was held in a 50 km by 100 km region surrounding Ames, Iowa, USA, between June 24 and July 12, 2002. The experiment had several objectives, including aircraft testing of new soil moisture sensor technologies, extension of soil moisture inversion algorithms to a broad range of vegetation conditions, and validation of soil moisture retrievals from the AMSR-E satellite on the NASA EOS Aqua platform. To satisfy these multiple objectives, a comprehensive ground-truth plan was implemented. Surface soil moisture content was measured daily at 81 sites using portable impedance probes and gravimetric data for probe validation. Thirty-three of these sites were located within the Walnut Creek watershed, while the remaining 48 were evenly-spaced along 4 N-S transects. In this presentation we characterize soil moisture variability within the entire region and its subregions, including the Walnut Creek watershed and AMSR-E footprints. Particular attention is paid to the temporal evolution of soil moisture variability and its behavior across scales

URL: http://www.ess.uci.edu/~famiglietti/html/smex02.html

H71E-07 1040h

Field-Scale Soil Moisture Spatial Structure Under Different Soil, Slope, Vegetation, and Precipitation During the Soil Moisture Experiment 2002 (SMEX02)

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The within-footprint variability of soil moisture depends on the complex interactions among precipitation, vegetation, topography, and soils. Thematic sampling of soil moisture under different combinations of these factors can reveal the intricacy of its variability and individual contributions of different factors. Near surface soil moisture measurements were conducted daily at seven fields during the Soil Moisture Experiment 2002 (SMEX02) for various combinations of soil texture, landscape position, vegetative cover, and hydro-climatic setup. Sampling in each field was made on multiple transects with various sampling densities based on one or more discernible factors(s) and themes. Surface soil moisture (between 0-6 cm depth) was measured using portable impedance probes. SMEX02 was characterized by a long dry down followed by significant rainfall having a strong spatial structure inside the study region. A preliminary statistical analysis of the within footprint variability for the observed fields is presented. The spatial and temporal variability among the fields are characterized and considered with respect to the predominant vegetation, climate, topography, and soils of the footprint. Surface soil texture, rolling topography, and row cropping dominated the spatial structure within the field, whereas precipitation patterns and vegetation cover were important contributors at the watershed and regional scale. The evolution of soil moisture structure is also considered using geostatistical and fractal analysis tools.

H71E-08 1055h

A New Distributed Hydrologic Model Based on ARHYTHM and RiverTools

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ARHYTHM is a distributed hydrologic/thermal model that was developed by Hinzman and colleagues (Zhang et al., 1999) for use in both arctic and nonarctic watersheds. It incorporates a number of important physical processes, including snowmelt, evapotranspiration, precipitation, subsurface (multi-layer, Darcy-law) flow, overland flow and channel flow. The snowmelt process can optionally be modeled with either the degree-day or energy balance method. Similarly, evapotranspiration can be modeled with either the Priestley-Taylor or energy balance method. The model is physically-based and has been tested for several watersheds on Alaska's North Slope. It consists of a geometric component that extracts a D8 flow grid from a DEM, in addition to the dynamic modeling component.

During the past year, the dynamic component of the ARHYTHM model has been rewritten and significantly extended using IDL (Interactive Data Language) and endowed with a user-friendly graphical interface. This interface has been designed to make it easy for users to code up new methods for any of the physical processes. Rather than rewrite the network extraction component, the model now draws on the powerful capabilities of RiverTools for the geometric component and visualization of results. Together, RiverTools and this new version of the ARHYTHM model make a powerful hydrologic modeling toolkit.

H71E-09 1110h

Assessing the impact of soil moisture initialization on seasonal predictions using the NCEP AGCM

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Due to the lack of long-term consistent soil moisture analysis, numerical studies of the impact of soil moisture on medium to seasonal range forecasts are often based on extreme or idealized conditions. In this study, the atmospheric predictability at seasonal scale is investigated using soil moisture analyses that are more realistic and model consistent. This is accomplished using the Air Force Weather Agency (AFWA) Agricultural Meteorology modeling system (AGRMET), an operational global database of land surface states and energy/water fluxes, and the NCEP Global Forecast System (GFS), a state-of-the-art general circulation model.

AFWA incorporated the NCEP community NOAH Land Surface Model (NOAH LSM) into AGRMET in late 1999. The soil hydrology physics are forced with analyses of shelter height temperature, relative humidity, and wind speed, short and longwave radition, and precipitation. As part of the efforts to unify land model in all NCEP global and regional models, NOAH LSM has been implemented into GFS in 2002. As AGRMET land states have spun up using same land physics that GFS executes, they provide ideal source of initial land states that are strictly self consistent with GFS land physics.

Two sets of summer-time ensemble integration of atmospheric model will be performed, one using climatological soil wetness derived from the NCEP/DOE Reanalysis (R-2) and the other using AGRMET soil wetness analysis as initial conditions. The geographical variations of the predictability of soil wetness, precipitation, and near surface temperature will be examined from this dataset.

H71E-10 1125h

Determination of Soil Water Regime Based on Ground-Based Microwave Radiometry Measurements

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The primary objective of this project is to link remotely sensed surface water contents to the soil water regime, in particular to the regime of structured soils. We attempt to use the dynamics of spatially averaged surface water contents measured with microwave radiometry to predict preferential infiltration and drainage. Under field conditions the so-called macropore flow plays an important role in the infiltration and drainage behavior of a soil, as well as in the mass transfer of all sorts of solutes. These rapid processes are only detectable during the first few hours after a rainfall event, when most of the larger pores are still water filled. The main focus of our project lies in an areal integration of such processes on a field scale. For this reason, we depend on areal data with a high temporal resolution that allow to characterize the soil water dynamics.

We present a field experiment with two different ground-based radiometers (1.4 GHz and 11.4 GHz, respectively) centered at a 5 m x 10 m bare soil plot. The brightness temperature measured with passive microwave sensors contains information on surface water content that is already spatially averaged. Furthermore the water content was measured in-situ with time domain reflectometry probes (TDR) assembled at five depths. In the same depths we measured matric potential (pressure head of soil water) and soil temperature. These data were recorded every 30 min from May to July 2002.

We illustrate the implications of the results from this field campaign on the determination of the soil water regime.

Based on the van Genuchten-Mualem model for the soil hydraulic functions we investigate how the hydraulic properties affect the dynamics of the topsoil water content and in how far we can estimate the hydraulic properties with inverse modeling.

URL: http://www.ito.umnw.ethz.ch/SoilPhys/staff/schneeberger/work.htm

H71F MCC: 103 Sunday 0830h

The Science and Uncertainty of River Management and Restoration I *(joint with B, T, PA)*

Presiding: **A Collison,** Philip Williams and Associates**; S Darby,** University of Southampton**; P Downs,** Stillwater Sciences**; D Sear,** University of Southampton

H71F-01 0835h INVITED

Uncertainty at the Source: Science for River Restoration

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Sustainable river restoration depends on effective predictive science leading to sound planning, design, and decision-making. Recent American experience has shown that fluvial geomorphology must address the following sources of uncertainty to reach its full potential as a partner in river restoration. (1) Science must take a more active role in establishing realistic goals for restoration; (2) established theory should be more fully exploited applications in restoration; (3) established theory must be improved by including role of humans and their societies; (4) site-based approaches need to be supplemented by improved watershed perspectives; (5) geomorphic science must build better connections with the biological sciences and engineering; (6) uncertainty needs to be more fully explored and quantified in geomorphic predictions; (7) uncertainty should be more effectively communicated to decision-makers and the public in quantitative and qualitative terms; (8) researchers and decision-makers need to deal more effectively with their biases and avoid advocacy science. From a philosophical perspective, researchers in fluvial geomorphology must come to recognize that their work must not only be good science, it must also be useful science.

H71F-02 0850h

The Grand Canyon Monitoring and Research Center's Role in Colorado River Ecosystem Science Below Glen Canyon Dam: An Overview on Science-Based River Management

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Impacts of Glen Canyon Dam (GCD) operations on downstream resources have been intensively studied by scientists and engineers since the early 1970s. In 1989, the Secretary of the Interior directed the Bureau of Reclamation to conduct the first-ever retroactive environmental compliance on operations of a large dam. Studies focused on linkages between flows and depletion of sand bars, endangered species conservation, including the humpback chub (*Gila cypha*), recreation and economic resources, as well as archeological sites preserved in fluvial deposits. The Grand Canyon Monitoring and Research Center (GCMRC) was established in 1995, following completion of this major environmental impact statement (EIS). The EIS preferred alternative, was incorporated into the Secretary of the Interior's Record-of-Decision (ROD) in 1996, following successful completion of a large-scale flow experiment. The modified-low-fluctuating-flow operating strategy at Glen Canyon Dam allows for continued diurnal fluctuations to meet power demand, but restricts up-ramp and down-ramp rates and total daily range of fluctuations. In 1997, the Secretary established the Glen Canyon Adaptive Management Workgroup (AMP) as a Federal advisory committee. The purpose of the committee is to provide recommendations to the Secretary on the effectiveness of the ROD, as well as to identify and recommend science-based adjustments to the ROD that might better achieve restoration and maintenance of downstream resources.

Adaptive management is based on the premise that ecosystem responses to management actions are often unpredictable. However, if such actions are undertaken as scientific experiments, then outcomes can provide new information to managers on the range of possibilities that exist for achieving restoration objectives. Large-scale flow experiments at Glen Canyon Dam, as well as ongoing monitoring and research since 1995, have refuted some of the original EIS hypotheses. Some resource trends under the ROD have been opposite to EIS predictions, such as continued declines in native fishes and sand resources. While new information from the science program has helped managers identify false hypotheses, it has also led to many new hypotheses about ecosystem responses to dam operations, especially related to native and non-native fish population dynamics and interactions. Although the scientific method has reduced uncertainty in some areas of the program, uncertainties have increased in other critical areas.

The GCMRC has recently proposed a multi-year plan of large-scale experiments to the AMP as a means of reducing uncertainties related to sediment and fisheries. The initial elements of the science experiment have been embraced by most managers in the AMP, and hopefully will be implemented in winter 2002-03. Although the process of adaptive management experimentation is proving to be an effective approach for reducing management uncertainty, it requires a long-term commitment on the part of river managers to be successful. The investment in science-based river management and restoration programs can result in multiple returns when new knowledge about fluvial ecosystem processes and responses is transferable to other projects.

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Science, Uncertainty, and Adaptive Management in Large River Restoration Programs: Trinity River example

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Following construction of Trinity and Lewiston dams on the upper Trinity River in 1964, dam induced changes to streamflows and sediment regime had severely simplified channel morphology and aquatic habitat downstream of the dams. This habitat change, combined with blocked access to over 100 miles of

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