Brief Article

The Author

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Synthesis of these and other references suggests that following approaches to watershed subdivision (in the absence of obvious natural features and flow regulation structures) have modeling value:

1. An Iso-temporal approach, where each sub-watershed is selected to have about the same characteristic response time (i.e. T_c). This particular approach may have great value in concurrent flooding (concurrent arrival times of flood waves). A challenge of this conceptualization is that lumped systems will necessarily be replaced by routed systems and any gain in certainty by using smaller sub-basins may be more than offset by increased uncertainty caused by routing. Despite this important criticism, the researchers still feel this is an line of investigation that needs consideration. At some scale of high subdivision, the entire runoff process that is currently explained using unit hydrographs becomes entirely replaced by hydraulic elements; interestingly the hydrographs “look” like convolved unit hydrographs so the accepted connection between the physical processes in a distributed hydraulic model and the lumped hydrologic model are well manifest in this sense.

2. An Iso-characteristic approach, where each sub-basin has about the same physical characteristic (area,length, etc.). Drainage area ratios would fall into this approach. The characteristics may be subtle – one paper presented at the 2006 American Geophysical Union used contiguous areas of similar slope to define watershed subareas (McGuire , 2006). While watershed subdivision was not the focus of the particular paper, nevertheless the idea appeared sound. The San Bernardino manual seems to imply a range of area ratios that are acceptable for preserving sufficient model believability, again a spatial characteristic based concept.

3. A scoring approach. Scoring is similar to the above concepts, except a set of characteristics is assigned a score; similar scores that are geographically connected are selected as watersheds. The scoring approach could admit descriptors not easily quantified numerically. For example the use of binary variables in 0-4193 and 0-4696 to account for the effect of developed/undeveloped and rocky/non-rocky are arguably

scoring approaches.

4. Gage defined approach where the locations of existing gages are used to subdivide a watershed not necessarily a modeling tool, but a good comparative tool. An extension would be to locate good gage locations based on measuring requirements and use these locations to divide a watershed.

5. Stream-order/bifurcation approach. Watersheds are subdivided based on branches in the dendritic drainage network. Several papers at 2006 American Geophysical Union used this approach to divide research watersheds for water quality and nutrient transport studies.

6. Ad-hoc. This approach is a research-only approach where basins would be defined at random, perhaps preserving some minimum measure. These random subareas would then be used to simulate runoff and these results compared to observations on the same watershed. Patterns that best agree with observations would be saved and analyzed to determine what physical features are common to good subdivisions (i.e. iso-temporal, iso-characteristic, etc.)

The implications are that a defendable systematic approach (iso-temporal or iso-characteristic) are implementable in a practical matter and this acknowledgement is applied in part of the research work underway[1].

The ad-hoc approach, while not practical for routing application, is a valuable research direction and it too is under investigation.

1 References Cited

McGuire, K., J., McDonnell, J.J., 2006. "The role of hillslopes in stream flow response: connectivity, flow path, and transit time." Eos Transactions of American Geophysics Union, Vol. 87, No. 52, Abstract H11A-1231.

2 Related Documents

The following are abstracts of papers and posters presented at the 2006 Fall American Geophysical Union Meeting. None of the posters were directly on the topic of "watershed subdivision," but the posters listed had some aspect that the researcher thought had merit

[1]These approaches are being investigated as part of Thuy Luong's thesis work at the University of Houston.

in the context of the subdivision problem. The posters have additional value in presenting a "current-events" snapshot of the broader research questions being addressed by the geosciences community.

For citing these posters the AGU recomends the following citation structure:
Author(s) 2006. "Title." Eos Transactions of American Geophysics Union, Vol. 87, No. 52, Abstract XXXX-XXXX.

H11A-1229

"Understanding Surface water – Ground water Interactions in Arkansas-Red River Basin using Coupled Modeling"

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Subsurface water exists primarily as groundwater and also in small quantity as soil water in the unsaturated zone. This soil water plays a vital role in the hydrologic cycle by supporting plant growth, regulating the amount of water lost to evapo-transpiration and affecting the surface water – groundwater interaction to a certain extent. As such, the interaction between surface water and groundwater is complex and little understood. This study aims at investigating the surface water–groundwater interaction in the Arkansas-Red river basin, using a coupled modeling platform. For this purpose, an ecohydrological model (SWAP) has been coupled with the groundwater model (MODFLOW). Inputs to this coupled model are collected from NEXRAD precipitation data at a resolution of 4 km, meteorological forcings from Oklahoma mesonet and NCDC sites, STATSGO soil property data, LAI (Leaf Area Index) data from MODIS at a resolution of 1 km, and DEM (Digital Elevation Model). For numerical modeling, a spatial resolution of 1 km and a temporal resolution of one day is used. The modeled base flow and total groundwater storage change would be tested using ground water table observation data. The modeled ground water storage is further improved using GRACE (Gravity Recovery and Climate Experiment) satellite data at a resolution of 400 km, with the help of appropriate data assimilation technique.

TxDOT Researcher's Comments: Used GIS to parameterize two models. Limited presentation on parameter uncertainty, not sure how applicable to smaller scale models approach has. Appears that ET and infiltration are used to adjust match to groundwater storage.

H11A-1230

"Solute Response To Arid-Climate Managed-River Flow During Storm Events"

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Storm pulses are widely used in unmanaged, temperate and subtropical river systems to resolve in-stream surface and subsurface flow components. Resulting catchment-scale hydrochemical mixing models yield insight into mechanisms of solute transport. Managed systems are far more complicated due to the human need for high quality water resources, which drives processes that are superimposed on most, if not all, of the unmanaged components. As an example, an increasingly large portion of the water supply for the

Phoenix metropolitan area is derived from multiple surface water sources that are impounded, diverted and otherwise managed upstream from the urban core that consumes the water and produces anthropogenic impacts. During large storm events this managed system is perturbed towards natural behavior as it receives inputs from natural hydrologic pathways in addition to impervious surfaces and storm water drainage channels. Our goals in studying managed river systems during this critical transition state are to determine how the well-characterized behavior of natural systems break down as the system responds then returns to its managed state. Using storm events as perturbations we can contrast an arid managed system with the unmanaged system it approaches during the storm event. In the process, we can extract geochemical consequences specifically related to unknown urban components in the form of chemical fingerprints. The effects of river management on solute behavior were assessed by taking advantage of several anomalously heavy winter storm events in late 2004 and early 2005 using a rigorous sampling routine. Several hundred samples collected between January and October 2005 were analyzed for major ion, isotopic, and trace metal concentrations with 78 individual measurements for each sample. The data are used to resolve managed watershed processes, mechanisms of solute transport and river mixing from anthropogenic inputs. Our results show that concentrations of major solutes change slowly and are independent of discharge downstream from the dams on two major tributaries. This is indicative of reservoir release water. In addition, a third input is derived from the Colorado River via the Central Arizona Project canal system. Cross plots including concentrations of solutes such as nitrate and sulfate from downstream of the confluence indicate at least three end-member sources, as do Piper diagrams using major anion and cation data. Dynamic contributions from natural event water and urban inputs can be resolved from the slowly changing release water, and may dictate the short-term transport of pollutants during the storm-induced transition state.

TxDOT Researcher's Comments: Used regulatory structures to introduce tracers. Transit times not clear in actual presentation. Clever use of tracers and controlled water releases.

H11A-1231

"The role of hillslopes in stream flow response: connectivity, flow path, and transit time"

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Subsurface flow from hillslopes is widely recognized as an important contributor to stream flow generation; however, processes that control how and when hillslopes connect to streams remain unclear. Much of the difficulty in deciphering hillslope response in the stream is due to riparian zone modulation of these inputs. We investigated stream and hillslope runoff dynamics in a 10 ha catchment in the western Cascades of Oregon where the riparian zone has been removed by debris flows, providing an unambiguous hillslope hydrologic signal to the stream channel. Water transit time was used as a framework to develop a conceptual stream flow generation model for the small basin. We based our conceptualization on observations of hydrometric, stable isotope, and applied tracer responses and computed transit times for multiple runoff components using a simple linear systems model. Event water mean transit times (8 to 34 h) and rapid breakthrough from applied hillslope tracer additions, demonstrated that contributing areas extend far upslope during events. Despite rapid hillslope transport processes during events, vadose zone water and runoff mean transit times during non-storm conditions were greater than the timescale of storm events. Vadose zone water mean transit times ranged between 10 and 25 days. Hillslope seepage and catchment baseflow mean transit times were between 1 and 2 years. We describe a conceptual model that captures variable physical flow pathways and transit times through changing antecedent wetness conditions that illustrate the different stages of hillslope and stream connectivity.

TxDOT Researcher's Comments: Used GIS and slopes, soil types, and other characteristics. Grouped characteristics by location to identify subwatersheds. Goal was not same as our research but the use of hydrologic response units that are physically connected was clever. Tracer tests are used to test research hypotheses.

H11A-1232

"Linking Rainfall, Soil Water Movement, and Groundwater Dynamics to Runoff in a Steep Hillslope: A Topdown Approach"

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The causal linkages between rainfall patterns, soil water response, development of transient groundwater and resulting subsurface stormflow on steep hillslopes remains poorly understood. Most studies to date have relied on short term (hours to days) datasets to characterize the runoff generation process of hillslopes or focused on one part of the system. We link rainfall, soil water movement, and groundwater dynamics for a highly instrumented hillslope at Watershed 10 at the H.J. Andrews Experimental Forest in Oregon, USA. Our hydrometric data from groundwater wells, tensiometers, soil moisture probes and hillslope runoff from a 10 meter wide trench were collected for a period of one year beginning in Fall 2004. This dataset enabled us to isolate and identify through data mining techniques how rainfall patterns control soil water movement, groundwater dynamics and subsurface stormflow under different antecedent wetness conditions. (Un)saturated fluxes, both vertical and lateral at 30 and 70 cm, calculated from the tensiometers, increased exponentially with a linear increase in mean or maximum intensity. The timelag between rainfall intensity and soil water flux, based on linear regression analysis, decreased with wetter conditions. Transient saturation at subtle changes in hydraulic conductivity within the soil profile occurred during the storm peaks. Groundwater development was very patchy, with maximum heights of about 20 cm above the bedrock layer. The relationship between groundwater height and hillslope discharge was non-linear. Tree regression analysis of hillslope discharge showed that during high flow conditions, antecedent wetness and mean and maximum intensity dominated system behavior. At low flow conditions, antecedent wetness alone appeared to predict hillslope discharge. Applying these data mining techniques improved our understanding of the hierarchy of process controls on hillslope runoff and uncovered new predictive rules for subsurface flow generation.

TxDOT Researcher's Comments: Companion to McGuire paper. Focused on the infiltration (loss model) signal. Also explicit mention of lag time as a hydrologic variable of interest.

H11A-1234

"The Integrated Landscape Hydrology Model (ILHM), a Fully-Distributed Approach to Simulate Regional Watershed Hydrologic Processes"

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Modeling fine-scale regional landscape and subsurface hydrology with fully-distributed process models requires data and computational resources that have only recently become available. For this reason most hydrologic models either do not represent crucial hydrologic processes or are not practical for regional-scale

simulations. To overcome these limitations we linked a set of existing codes with novel approaches in the new Integrated Landscape Hydrology Model (ILHM), designed to integrate widely-available GIS and remotely-sensed data using a simple parameterization The ILHM is a loosely-coupled suite of codes that allows fine-scale numerical modeling for some processes while integrating simpler water-balance models at disparate temporal and spatial scales. This approach enables individual process models to be swapped with different modules or with measured data. Currently, the ILHM includes codes that simulate canopy and soil processes, snowpack accumulation and melt, surface ponding and runoff, shallow sub-surface flow, and both unsaturated and saturated groundwater flow. The ILHM also has potential as a tool to simulate fluxes through large ungaged basins and evaluate historical and future hydrologic scenarios. We present an application of the ILHM to a 137 square kilometer catchment within the larger Muskegon River Watershed in northern-lower Michigan. A comparison of model outputs to measured and gaged stream discharges demonstrates that the ILHM is capable of predicting hydrologic fluxes with reasonable accuracy without significant parameter calibration. In addition, the model results suggest interesting and important linkages between land use and groundwater recharge.

TxDOT Researcher's Comments: Used GIS and existing computer codes to develop continuous simulation responses. Performance seems about same as lumped parameter (researcher opinion). Vague presentation on how results were interpreted.

H11A-1242

"Coupling of Hydrological Models to Assess the Impacts of Changes in Surface and Subsurface Water Extraction on Stream Flows"

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Although it is commonly understood that the extraction of groundwater from the natural environment can have a significant affect on the hydrological processes throughout a watershed, the precise affect on different processes is not well understood. Existing models are able to accurately simulate the effect of extraction on individual systems, but holistic models are needed to study the effect across different systems. The primary objective of this study is the development, application and investigation of a coupled modeling approach, combining two well- known models, the United States Geological Survey's Modular Finite-Difference Groundwater Flow Model (MODFLOW) and the topography based TopModel, in order to simulate complex hydrological processes in a mesoscale watershed. The models have been coupled through the use of the InCouple model coupling framework. Through the use of lightweight model interfaces, prototype couplings between the models were quickly created with minimal changes to the model source codes. These couplings, though, were largely simplified (not spatially distributed, one-way interaction only, and used preliminary data from the Tenmile watershed in Washington State, USA). The water table elevations simulated by MODFLOW were used by TopModel in its simulation of runoff. In our current work, we extend this simple coupling such that the spatial distribution of the groundwater is represented in MODFLOW, and the interaction between the models is bidirectional such that TopModel uses the water table elevations simulated by MODFLOW, and the recharge calculated by TopModel affects the water table elevation simulation in MODFLOW. We present the results of this bidirectional interaction between the models as applied to our study site. Our long term goal is to use the rapid prototyping capability of the InCouple framework to couple other models to MODFLOW to develop holistic models that can be used to study the effects of groundwater extraction at the mesoscale watershed level.

TxDOT Researcher's Comments: Integrated MODFLOW and TOPMODEL for large-scale watershed simulations. Appears to be continuous simulation. Limited performance results (none) were presented in the poster. No attempt to lump – all watersheds are discritized to the DEM resolution.

H13A-1349

"Linking the topography signature of LIDAR-derived vegetation types and geomorphic processes as preliminary steps in integrating landscape evolution with vegetation dynamics"

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In the Italian Alps, dominated by a high altitude climate and characterized by extreme slope movement processes, topography plays a key role in the redistribution of vegetation over the landscape. There is significant evidence that vegetation distribution on the Alpine basins influences the frequency and magnitude of sediment yields. In this study we investigate the links between topography and vegetation species in a small Alpine catchment with an elevation range of 1500 to 2000 m a.s.l., with cold snowy winters, and wet summers, in order to decipher the influence of biota on geomorphic processes in atypical high-latitude Alpine headwater setting. In the study area vegetation is mostly represented by grass species (high altitude grassland), but also shrubs (Alnus viridis), and high tree forest (Picea abies) are common. We evaluate the distribution of vegetation canopies using LIDAR- derived vegetation data. We analyzed the vertical elevation of different vegetation canopy surface layers, and we derived the spatial variation of vegetation species following their heights as surveyed in the field. Then we use a high resolution DTM (Digital Terrain Model), evaluated from filtered bare ground LIDAR points, to derive some mathematical attributes of landscape morphology including slope gradient, drainage area, aspect, convergence and topographic wetness index, slope – area diagrams and power-law distribution of areas. We discussed the relationships between vegetation species distribution and landform properties.

TxDOT Researcher's Comments: Note the emphasis on morphology at end of abstract. These researchers are attempting to address very similar issue, but focus in on solids (sediment) production. Concepts of slope, area, and slope-area may have value in subdivision research.

H13A-1352

"Upscaling biological quantities in a watershed: combining local predictors with hydro- geomorphological scaling laws"

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Recent efforts have demonstrated that local periphyton biomass can be predicted to satisfactory accuracy by local physiographic and geomorphic properties in a steep upland stream. For example, periphyton biomass at a point along a river can be predicted by a nonlinear relationship that involves average cross-sectional depth, maximum width, average velocity, exposure to light and nitrate concentration. In this paper, we demonstrate how such local relationships between biotic and abiotic variables can be upscaled to a river reach by using known scaling laws between discharge and channel properties, known as hydraulic geometry. Using high resolution topography to resolve the spatial variability of channel quantities, we show that average reach periphyton biomass can be estimated to greater accuracy using upscaling of local geomorphic predictors rather than traditional averaging of discrete samples. The implications of this work for sampling design and for interpreting sparse local observations in the context of reach average quantities are also discussed.

TxDOT Researcher's Comments: Not directly related. Scaling laws to locate where to make measurements and to convert averaged and point measurements is worth future study.

H13A-1365

"On the topographic imprint of vegetation: Results from field observations and DEM analysis of small semiarid basins"

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Terrestrial landforms result from the complex interactions between biotic and abiotic earth surface processes forced by climate and tectonics. Understanding the coupled evolution of the physical landscape system with its biology is a fundamental problem in hydrological sciences. One efficient way to study this coupling is to quantify the differences in vegetation patterns on neighboring hillslopes that are within the same climate, geology and catchment area. Vegetation patterns in the southwestern US are typically organized with respect to the topographic texture with repeated bands consisting of more mesic plant species in the wetter north-facing slopes, and communities dominated by xeric species on the drier south-facing slopes, especially where climate promotes ecosystem coexistence. There is evidence that over the long-term such differences in plant species lead to differential soil and landform development on hillslopes with opposing aspects. In this study we report preliminary results on the mathematical properties of landscape morphology of various hillslope aspects in several small-scale (¡10km2) semiarid catchments near Socorro New Mexico based on field measurements of hillslope profiles and digital elevation model analysis. In the basins studied, the north-facing hillslopes are composed of oneseed juniper (Juniperus monosperma) and several grass species, have convex hilltops and planar slopes atypical of diffusive landforms. The south-facing slopes are primarily creosote bush (Larrea tridentata), and visually more dissected and concave than the north facing slopes, displaying geomorphic signatures of fluvial erosion. Along the head slopes, often an active ecotone serves as a boundary between the ecosystems. Our results suggest that even subtle differences in the vegetation type under essentially the same climate and geologic controls leave detectable signatures on the mathematical properties of landscape organization and morphology.

TxDOT Researcher's Comments: More GIS and DEM work – related to biology and solids production. Paper notes that orientation matters (North slopes are different than South slopes) in the context of *vegetation type and consequently erosion patterns. Limited practical use for subdivision project, but again an area worthy of future consideration.*

H13A-1372

"Exploring possible tight inter-connections between climate, soil, topography through constraining by empirical measure of annual water balance"

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Horton overland flow, Dunne overland flow and subsurface flow are the three dominant mechanisms contributing to runoff generation. The Dunne diagram (Dunne, 1978) qualitatively interprets that the occurrence and dominance of different mechanisms are significantly affected by climatic conditions, soil characteristics and topography. In this work, the climate, soil and topographic controls on annual water balance are examined. A simple distributed hydrologic model has been built for this purpose, which is comprehensive enough to simulate the effects of different combinations of climate, soil and topography, and generate a diversity of runoff generation mechanisms. A small set of dimensionless similarity variables, which are physically meaningful, have been shown to explain the competition between the wetting, drying, storage and drainage functions of the watershed that underlie this model predicted behavior. Each combination of these dimensionless numbers could be feasible in theory, but only some combinations actually occur in nature. By constraining the predictions of the model with the empirical Budyko curve, we narrow down to these feasible combinations. At the very least the resulting quantitative climate, soil and topography interconnections could be potentially tested in the field, and if deemed reasonable, also used to constrain hydrological model predictions. The paper will present results from this thought experiment and the ramifications of the results for future field studies and hydrological modeling.

TxDOT Researcher's Comments: Significant work in our context. Researchers have examined loss models and highly distributed models, then by non-dimensionalizing have lumped results (unintentionally). Little immediate practical value, but suggests current research directions are meaningful.

H13B-1376

"Impacts of climate variability and change on flood frequency: a comparative study of catchments in Perth, Newcastle and Darwin, Australia"

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Traditional flood frequency analysis assumes stationarity, and thus cannot account for non-satationarity caused by long-term climate variability and change. In this study, we demonstrate that the probability distribution of annual maximum floods is functional upon multi-annual, multi-decadal trends and climate change in local climate. Three locations in Australia, namely Perth, Newcastle and Darwin are selected and compared to explore the impact of climate variability and change on flood frequency. Analysis is performed using a stochastic rainfall model coupled with a continuous rainfall-runoff model that captures the water

balance variability at a multiplicity of time scales ranging from event to seasonal, inter-annual and inter-decadal time scales. Climate variability and change are incorporated using different parameterisations of the rainfall model, based upon analysis of observed rainfall data and selected climate scenarios. We present six climate scenarios linked between ENSO (El Nino Southern Oscillation) and IPO (Interdecadal Pacific Oscillation) in Newcastle, and six different climate scenarios for Perth and Darwin that are related to ENSO and an apparent shift in climate, identified by statistical analysis, occurring from 1970. The results show that La Nina (ENSO negative) years cause higher annual maximum floods compared to El Nino (ENSO positive) and ENSO neutral years during both IPO (+) and IPO(-) in Newcastle and pre- and post-1970 in Darwin and Perth. The impact of ENSO on annual maximum floods in Newcastle cacthment is enhanced when the IPO is negative. For Perth, the impact of ENSO weakens post-1970, while it strengthens in Darwin. This research shows that non-stationarity in climate associated with ENSO and long term climate shifts has a significant impact upon flood frequency in a variety of Australian climates.

TxDOT Researcher's Comments: Comparative study of two watersheds was of interest in this poster. Authors alluded to difficulty in finding otherwise similar watersheds to examine spatial effect of climate on response. Such problem is related to subdivision issue.

H13B-1377

"The Effects of Land use on Soil Properties and Runoff Response at the CATIE Farm, Turrialba, Costa Rica."

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Runoff response in humid tropical areas often is assumed to occur due to infiltration excess. Rainfall intensities in these areas can be monstruous. However, at the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) farm near Turrialba in Costa Rica, we have observed that volcanically derived soils have very high infiltration capacities, depending on the land use type, suggesting that saturation excess overland flow mechanism are important in explaining the runoff response. In this study we compared field-scale (1-6 ha) runoff response of four different types of prominent land use on the CATIE farm: forest, a coffee agroforestry system, sugar cane, and pasture. The research site is located at approximately 650 masl in deep soils on the tropical wet Caribbean slope of Costa Rica. Hydrograph analysis of observed runoff data suggest that the runoff mechanism in forest, coffee and sugar cane sites depends much more on the amount of soil storage (e.g. saturated-excess overland flow) than in the pasture site. The pasture site exhibits more of an infiltration-excess response. In this presentation we present differences in several soil properties that correlate with land use. We simulated measured runoff responses using the Soil Moisture Routing (SMR) model in this high rainfall, deep soil environment because of its ability to simulate saturation-excess overland flow and lateral flows.

TxDOT Researcher's Comments: A loss model study, sample sites were located ad-hoc. In our TxDOT work we have all used the infiltration-excess (Hortonian) approach as opposed to saturation-excess (Dunne) *approach.*

H13B-1385

"Evaluating the effect of land use land cover change in a rapidly urbanizing semi-arid watershed on estuarine freshwater inflows"

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Estuarine freshwater inflows along with their associated nutrient and metal delivery are influenced by the land use/land cover (LULC) and water management practices in the contributing watershed. This study evaluates the effect of rapid urbanization in the San Antonio River Watershed on the amount of freshwater inflow reaching the San Antonio-Guadalupe estuary on the Gulf Coast of Texas. Remotely sensed data from satellite imagery provided a source of reliable data for land use classification and land cover change analysis; while long time series of the geophysical signals of stream flow and precipitation provided the data needed to assess change in flow in the watershed. LULC was determined using LANDSAT (5 TM and 7 ETM) satellite images over 20 years (1985-2003). The LANDSAT images were classified using an ENVI. ISODATA classification scheme. Changes were quantified in terms of the urban expansion that had occurred in past 20 years using an urban index. Streamflow was analyzed using 20 years (1985-2004) of average daily discharge obtained from the USGS gauging station (08188500) closest to the headwaters of the estuary. Baseflow and storm flow were partitioned from total flow using a universally used baseflow separation technique. Precipitation data was obtained from an NCDC station in the watershed. Preliminary results indicate that the most significant change in land use over the 20 year period was an increase in the total amount of impervious area in the watershed. This increase in impervious area was accompanied by an increase in both total streamflow and in baseflow over the same period. The investigation did not show a significant change in total annual precipitation from 1990 to 2004. This suggests that the increase in streamflow was more influenced by LULC than climate change. One explanation for the increase in baseflow may be an increase in return flows resulting from an increase in the total number of wastewater treatment plants in the watershed.

TxDOT Researcher's Comments: Related to our unitgraph work, esp. the developed/undeveloped scoring approach. Limited value in watershed subdivision, but classification of watershed "types" implies subdivision in some sense.

H13B-1386

"Impacts of Land Cover Change on Natural Recharge Levels in the Semi-Arid Edwards Aquifer Region of Texas"

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Understanding historical land cover and land use, and other related changes within the hydrologic signals of a region is advantageous when modeling efforts are considered. However, incorporating different types of land cover changes for hydrologic prediction is not a well-understood task. From a water resources planning

and management perspective, this is of unique interest in semi-arid regions where water availability is often low and thus, water balance sensitivity may be high. The semi-arid Edwards Aquifer region of Texas has undergone measurable increases in both population and impervious surface area over the last twenty years, particularly in the greater metropolitan areas of San Antonio and Austin, the eighth and nineteenth largest cities in the United States, respectively. Consequently, it is expected that the hydrologic response of the Edwards Aquifer has also undergone changes. The Soil and Water Assessment Tool (SWAT) is a physically- based modeling tool for predicting the impacts of land management practices on water, sediment, and agricultural chemical yields. This work presents the results of an algorithm developed to utilize the SWAT model for estimating natural recharge levels in the semi-arid Edwards Aquifer region of Texas when land cover and land use, and other related system input changes are considered.

TxDOT Researcher's Comments: Used SWAT, poster implicitly subdivided by using different land use classifications. Responses are aggregated at watershed scale – effect of subdivision unable to be accessed.

H13I-05

"Modeled Response of the low Gradient Portions of the Fly and Strickland Rivers to Post- Glacial Sea-Level Rise"

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River valleys evolve in response to upstream boundary conditions such as water and sediment supply and to downstream conditions such as sea level. The low gradient sand-bed portion of the Fly River System in Papua New Guinea provides a unique opportunity to study the effect of sea level change on a system with significantly different sediment supplies to its two major tributaries. In its present-day state, the larger of the two main tributaries, the Strickland River, is significantly steeper and less flood prone than the smaller tributary, the middle Fly River (i.e. the Fly River above the confluence with the Strickland). The difference is usually ascribed to a more rapid and complete response to sea-level change along the Strickland River than along the middle Fly River driven by the significantly larger sediment supply to the Strickland. This hypothesis is tested using a numerical model for river valley evolution over 1000 to 10000 year timescales. The model includes the three main low- gradient sand-bed reaches in the system, the middle Fly and Strickland Rivers (above the confluence) and the Lower Fly River (below the confluence). The model is theoretically similar to other diffusion-based numerical models for valley infilling. However, the inclusion of backwater in the theory results in an advective-diffusive form that allows a new delta to automatically form upstream of an abandoned delta once sea level stabilizes. The low- stand longitudinal profile is not well constrained along any of the three low gradient reaches of the Fly River system. However, model results confirm that for several different hypothetical low-stand profiles and for sediment loads similar to those observed at present, the middle Fly River would not have been able to keep up with aggradation along the Lower Fly/Strickland axis of the system. The results imply that it is unlikely that the low- stand river channel bed was more than approximately 10 m below the present-day channel bed near the confluence, consistent with the few available field observations. This is not necessarily apparent if the evolution of Strickland/Lower Fly axis of the system is considered alone without the inclusion of the middle Fly River. The results further imply that at glacial low stand, the Lower Fly River may have passed through a – hard zone – that was significantly steeper than the present-day Lower Fly River.

TxDOT Researcher's Comments: Related to low-slope hydrology. Suggested stream-gradient evolution can *be explained/predicted by tail-water history.*

H13H-01 INVITED

"Doing Hydrology Backwards: Inferring Landscape-Scale Rainfall and Evapotranspiration From Streamflow Time Series"

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Catchment hydrology is controlled by processes and material properties that are complex, heterogeneous on all scales, and poorly characterized by direct measurement. This spatial heterogeneity and process complexity implies that any hydrologic model will necessarily entail substantial simplifications and generalizations. The essential question is which simplifications and generalizations are appropriate for the case at hand. Many 'physically based' hydrologic models are grounded in an implicit up-scaling premise, which assumes that the small-scale physics in the subsurface will 'scale up' such that the behavior at larger scales (e.g., hillslopes or catchments) will be described by the same governing equations (e.g., Darcy's Law, Richards' equation), with state variables (e.g., water flux, volumetric water content, hydraulic potential) that are averaged, and with 'effective' parameters that somehow subsume the heterogeneity of the subsurface. There are reasons to believe that this upscaling premise may often be incorrect, and that the effective governing equations for these heterogeneous systems may be different in form (not just different in the parameters) from the equations that describe the small- scale physics. Here I describe an approach for determining the constitutive equations that describe catchment behavior at the small-catchment scale. This approach considers the catchment as a first-order nonlinear dynamical system, and estimates its (nonlinear) governing equations at catchment scale, directly from field data. This approach assumes that discharge depends on the aggregate volume of water stored in the catchment, but makes no *a priori* assumption about the functional form of this storage-discharge relationship, instead determining it from rainfall-runoff data. This approach not only allows one to predict runoff from measurements of rainfall, but also allows one to do hydrology backwards: that is, to infer effective rainfall and evapotranspiration at whole-catchment scale, directly from runoff time-series data. This approach can potentially be used to ground-truth remote sensing estimates of rainfall and evapotranspiration time series.

TxDOT Researcher's Comments: Related to all our work. While not specifically on subdivision, the author's implication that doing hydrology backwards is a strong argument for our team's pursuit of the ad-hoc division research method as well as ensuring that any subdivision scheme aggregrate and dis-aggregate without impacting the lumped response signal.