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2003 RAY K. LINSLEY AWARD

Stephen J. Burges, Recipient

This award was established in 1986 to honor the first Vice President of AIH, Ray K. Linsley - one of the great leaders in the hydrological sciences. The award is presented annually, on the recommendation of the AIH Awards Committee, for a major contribution to the field of groundwater hydrology. The first Ray K. Linsley Award was presented to Peter O. Wolf at the AIH International Conference on Advances in Ground-Water Hydrology in Tampa on November 17, 1988.

Citation: Miguel A. Mariño

This award is named for the late Ray K. Linsley, a world-class hydrologist who for many years was a professor at Stanford University. This award means a lot, an awful lot, to Steve Burges because of the relationship he had with Ray Linsley.

Steve Burges has been on the faculty at the University of Washington since 1970, where he currently serves as Professor of Civil and Environmental Engineering. Steve received not one but two Bachelor's degrees (one in Physics and Mathematics and a second in Civil Engineering) from Newcastle University in Australia. He came to the States in 1967 to attend Stanford University, where he received Master's and Ph.D. degrees in Civil Engineering. He not only studied hydrology under Ray Linsley but became of one his close friends-a friendship that lasted until Linsley's death in 1990. It was at Stanford where Steve met his wife Sylvia in 1969; she was a graduate student at the time. She is now an environmental scientist in Seattle.

For the past 33 years, Steve has made significant and lasting contributions to the field of hydrology. In fact, he has contributed to an extraordinary range of hydrologic enquiry; particularly, predictions and their uncertainties. It is not surprising then that Steve has received many honors throughout his career . To name a few, he is a Fellow of the American Geophysical Union, a Fellow of the American Society of Civil Engineers, and a Fellow of the American Association for the Advancement of Science. He was chosen to deliver the Kisiel Memorial Lecture at the University of Arizona in 1997 and the Langbein Lecture at the AGU Spring Annual Meeting two years ago.

Steve has given generously of his time to the education of hydrologists in the U.S. and abroad. He has also given generously of his time to the service of professional societies. He has served as Editor of Water Resources Research, Chairman of the Horton Awards Committee of AGU, Chairman of the Horton Medal Committee of AGU, President of the Hydrology Section of AGU, chairman and member of various committees of the U.S. National Research Council as well as committees of ASCE and other societies. For seven years, he served as Chairman of the Linsley Award Committee of our Institute.

In summary, Steve has made an outstanding contribution to the science and practice of hydrology. His contributions have been both in research and in the practical application of outcomes of his research to real hydrologic problems. Many government and non-government organizations have benefited greatly from his work.

Appendix A

STEPHEN J. BURGES, RECIPIENT

It is indeed an honor to present to you this year's recipient of the Ray K. Linsley Award, Professor Stephen John Burges.

2003 Ray K. Linsley Award Recipient: Stephen J. Burges

Thank you Miguel for your most gracious and generous citation.

I am enormously grateful to the American Institute of Hydrology for honoring me with the 2003 Ray K Linsley Award. I join a distinguished group of fifteen international scientific and professional leaders who have received this award, thirteen of whom are living. I am honored that my name is now linked with Ray's in this way. He was a giant of the profession and one of my heroes.

My Connections with Ray Linsley

In my citation for the 1999 Ray K Linsley Award to Professor Peter Eagleson I wrote:

"Ray was my doctoral advisor at Stanford. His mentorship did not stop with my graduation in 1970. He was always available for advice; he was a strong supporter and inspiring friend. He was one of the clearest thinkers I have known and one of the rare academic leaders who saw where science, society, and the practice of engineering combined. In addition to his leadership in hydrologic education, research, and practice, he built the program on Engineering Economic Planning (EEP) at Stanford in the early 1960s to provided educational and research direction in public works planning. The major thrusts of the EEP program were in water resources and transportation."

I was a naïve twenty-three year old when I started my graduate studies at Stanford University. Bob Street guided me through my MS degree and then I worked with Ray (he was "Prof. Linsley" then) on a US Department of the Interior Office of Water Resources Research project to assess the uncertainties of a single purpose water resource project. Ray's objective was to gain a sense of the uncertainty in a project benefit/cost ratio so that better planning decisions could be made. This effort culminated in the publication of my doctoral thesis "Use of Stochastic Hydrology to Determine Storage Requirements for Reservoirs - A Critical Analysis", Report EEP-34, Program in Engineering Economic Planning, Stanford University, 1970.

I have been interested in all aspects of hydrology, hydrologic engineering, and water resources planning since my graduate work. I have had particularly strong interests in attempting to quantify uncertainties in all the work we do so that we might make better decisions and sharpen our science.

I have been guided in much of what I do by the summary final lecture that Ray gave in Spring 1968 for the course CEE 222 "Water Resources Planning" that emphasized Federal Water Planning in the US. I wrote in my notes the following:

"The Ten Commandments for Planning -- after Linsley"

1. There should be a serious attempt to define planning objectives.
2. More thorough preliminary feasibility studies are needed; Federal Authorization Studies are usually poorly made.
3. Less institutional bias is appropriate in planning. Planning activities should be separated from agency construction.

4. A large range of alternatives should be considered -- use imagination and remove institutional biases. Try to modify constraints and avoid blind use of standards.
5. Better communication of planning and planning alternatives is needed. Prepare reports for the lay public; existing reports are too technical. Use plain language; avoid technical jargon; leave out "garbage". Use pictures wherever possible and simplify all graphs and drawings.
6. We should make maximum and better use of analytical methods to enable us to do the job better and faster to help us reach decisions about alternatives.
7. Develop clearer policy about the intangibles including recreation, scenic beauty, and preservation of historic sites.
8. More local participation in planning and less Federal domination is needed.
9. There may be a need for planned research because research and development differ greatly. There must be pure research but we should plan carefully which of the research findings need to be developed.
10. Planning should always remain professional. It is unconscionable to fudge facts.

Item one is at the heart of any systematic approach to planning. Real, apparent, and hidden objectives must be identified otherwise the rest of the exercise is useless. Item four will always be relevant (Morgan, 1951). Items five and six addressed needs of the time and anticipated the enormous capability that is now available to us to display and explore various options. Item ten is his strongest statement; he was appalled that professionals would be less than truthful in what they did and he demanded ethical practice.

Ray made these observations during the early days of the National Water Commission, on which he served as a Commissioner. Much water planning in the US was dominated by federal agencies and public involvement was starting to be much more important in the overall process. This was the era when some engineers stood unwisely before their fellow citizens and suggested that the plans presented by the engineers were the best possible. Simple questions by members of the audience often were answered poorly or not at all. Many members of the wider public concluded that planning needed to be done better. The overall process is much better now as noted in the 1999 National Research Council report on "New Directions in Water Resources Planning for the U.S. Army Corps of Engineers" (NRC, 1999), but there is still room for improvement.

Ray asked me in 1975 to write a paper on the role of water resources systems engineering over the previous two hundred years for inclusion in an ASCE conference as part of the commemoration of the Nation's Bicentennial. I worked closely with Doug James (the 1997 Linsley Awardee) who spent Spring Quarter 1976 at the University of Washington while I was writing the paper. Gene Willeke also provided many thoughtful suggestions. Both Gene and Doug suggested that I examine the work of Arthur Morgan and particularly his work with the Miami Conservancy District to gain perspective about a broad systematic approach to water resources planning and engineering. I am grateful to all three for that opportunity. After reading about Morgan and his work I was surprised that Ray did not have us read as part of our suggested reading as graduate students some of the reports of the Miami Conservancy District and particularly Morgan's book "The Miami Conservancy District" (Morgan, 1951).

Morgan had articulated and implemented many of the ideas that Ray had shared with us. It is refreshing that one great water engineer developed an approach for the widest context of water resources planning and engineering for a pre depression era society, and another was attempting to direct others in productive ways during the decade of the 1960's when the society had changed considerably from the society Morgan knew in the Miami Valley of Ohio. I benefited enormously from writing the paper (Burges, 1979). It was during its preparation that I articulated my most complete description of what a "systematic approach" to civil engineering and water resources engineering could be.

A Self-Assessment of my Professional Work

I am first and foremost an engineering educator. My main work is in hydrology, but I have always had in the background of my thinking that I am a civil engineer and that what we do is to provide civil infrastructure in a heavily human influenced ecosystem. To that end I encourage my students to observe their world closely and to think at the most fundamental level about all that they do so that their professional work will lead to good solutions that are compatible with our place in the ecosystem.

I have been an educator since 1970. I soon concluded that the topics that we should choose for research are in those areas that we anticipate that we will need improved tools about twenty or more years ahead. I realized that much of what we attempt that is "new" may not work out. We need time to go through numerous development iterations to yield increased understanding and improved tools. That can take many years. I did not realize until the mid 1980s that because of this approach I wrote about two papers on any topic that I had chosen to investigate. Innovative research is much like the inventing process; the final product from any invention is, on average, about the thirty-fifth iteration of the original idea.

I also did not know then that Nobel Laureate, the late Sir Peter Medawar had already described the process of unproductive research. It was in January 1993 that I discovered and read Medawar's book Pluto's Republic. In his essay on induction in this book Medawar wrote: "I reckon that for all the use it has been to science about four-fifths of my time has been wasted, and I believe this to be the common lot of people who are not merely playing follow-my-leader in research". I concluded that if only about 20 % of Sir Peter's research was productive, the rest of us would be doing well if 5% of ours was potentially valuable. I had stumbled in my own way upon the reality that much of what we do does not pan out. That means that much of what is offered for publication would be better if culled. I read Medawar's wonderful book "Advice to a Young Scientist" a few years earlier. I regret that I had not found and read these gems sooner. I now make sure that my younger colleagues are aware of some of Medawar's brilliant writings.

The subjects that have caught my attention and occupied much of my time include:

<u>1970s</u>

Water resource system engineering in the spirit of Arthur Morgan and The Miami Conservancy District
Uncertainty propagation in water quality models
Conjunctive use of ground and surface water
Cyclic storage of ground and surface water
Models of long-term hydrologic persistence
Design of water quality trend detection networks
Detection of climate change and its influence on hydrologic design
Reservoir design capacities for various models of seasonal and long-term stochastic variability Optimization for sizing urban drainage networks
Uncertainty in flood plain mapping
Urban hydrology

1980s
Conditional seasonal runoff volume forecasts
Error propagation in continuous simulation hydrologic models
Calibration and testing of hydrologic models
Optimal multiple-purpose reservoir operation
Estimation of bias and confidence intervals of probability distributions used in hydrology
Urban hydrology
Field programs to assess utility of urban runoff detention facilities
Field programs to determine the hydrologic balance of small (under 40 ha) basins

1990s
Moving organic debris dams
Critical evaluation of rainfall-runoff models
Influence of channel-flood plain hydraulic properties on estimated flood frequencies
Surface flow with a realistic digital elevation model
Flood flow volumes for flood reservoir design and operation
Land surface water and energy fluxes
Channel planform and topological randomness
Hydrologic effects of land use change in suburban settings
Adaptive modeling and monitoring in small basins
Radar rainfall measurement - Goodwin Creek Mississippi (1996-)
Monitoring of a network of rain gauges Seattle (1996-)
Monitoring the mass balance from small hill slopes Seattle (1994-)

2000-
Hydrologic mitigation using on-site residential storm water detention
Thermal remote sensing of river temperature
Monitoring and distributed modeling of a small urban catchment (Seattle)
Bedload movement in gravel bed streams
Hydrologic model components and model calibration

All of this work has been done (and is continuing to be done) with absolutely excellent and splendid colleagues who have taught me over the years.

The Value of Observations

The 2002 Linsley Award recipient, Professor David Pilgrim, emphasized the value of field observation and noted: "Getting one's hands dirty and feet wet can bring hydrology to life and create a critical attitude to methods adopted in practice".

I learned a huge amount doing my first stream gauging for an instream flow assessment in 1972 in the White River, WA. The work on assessing the effectiveness of urban runoff detention facilities (1980-1982) was rich in experience. We investigated more than 100 detention facilities and determined that only two could be monitored without making major engineering changes. As an out growth of that experience we recommended to the King County Council, WA that the staff be given authority to ask for monitoring capability to be designed into future facilities as needed. I have been leading class field trips to catchments since the late 1970s and continue to observe and learn about hydrologic processes and difficulties of measurement. Our work learning about hydrologic processes in two local-area catchments from 1989 through 1993 was enormously enlightening. The larger was 37 ha and forested. The smaller was 17 ha and urbanized. This forced me to think much more closely about all elements of the hydrologic cycle in the mass balance. The key findings are in Wigmosta and Burges(1997) and Burges et al (1998). Few data are available at this scale, the scale where critical actions that are taken have significant cumulative hydrological, geomorphic, and ecological consequences. My work with Matthias Steiner and Jim Smith (Princeton) and colleagues from the US Department of Agriculture National Sedimentation Laboratory, Oxford Mississippi using Radars to measure rainfall at the ARS Goodwin Creek experimental watershed has also been invaluable in focusing my attention on quality assurance and quality control issues associated with rainfall measurement. We have added pit gauges to augment the extensive network of rain gauges to provide the needed accuracy for our work. Our data are precious and are hard won. We have reported on some of this work in Steiner et al (1999).

I have been maintaining a personal research site since 1997 at the University of Washington's Center for Urban Horticulture where I monitor the flow from seven small constructed hillslopes. These experimental hillslopes, constructed in 1994 and described in Kolsti et al (1995), were established to determine the effectiveness of adding compost to till to create soils that would mitigate some of the deleterious influences of urbanization, namely removal of soil and severe compaction of the residual soil around houses and other buildings. Each plot has dimensions: length 9.75 m, width 2.44 m, and depth 0.30 m. The slope is 5%. The length and depth were chosen to be representative of typical suburban lawns in the Seattle region.

In the course of studying these, I have had to investigate closely the attributes of rain gauges and how they are deployed. I have concluded that the only useful liquid water rain gauges are "pit gauges". Any gauge exposed to wind only gives an uncorrectable biased index of actual rainfall. These shortcomings have been documented by others including Duchon and Essenberg (2001) where they indicate the recorded storm under catch for a wind influenced gauge is as much as 15% of pit gauge recorded rainfall in Oklahoma. I have concluded that we can make excellent "point" measurements from a cluster of three relatively closely spaced pit rain gauges (Burges, 2003). The existing network of rain gauges in the US is useful for operational purposes, but has extremely limited capability for any question of research concerned with improving estimates of the water balance.

Hydrologic Variability and its Societal Importance

I chose to work on issues of hydrologic uncertainty early in my career. Developing capabilities to consider the stochastic variability in river flow and how that influences the reliability of water supply systems interested me (and Ray Linsley) in 1969 when the population of the US reached 200 million. At the end of 2003 the population is about 291 million and the physical water demand levels have increased. We are at the level of demand where the form of variability in river flow, including persistence that can be multiple decades long, is important to know. We have in place tools that were developed in the 1970s that permit us to assess system reliability. We do not know, however, if the assumed forms of persistence are correct. I have covered this topic comprehensively in my 2001 Langbein Lecture that is accessible as a webcast from the American Geophysical Union at http://www.agu.org/webcast/archive.html.

Appendix A

The Future

I have written on several occasions about forward direction for our science and practice. Once was as a guest editor of a special issue of Water Resources Research "Trends and Directions in Hydrology" in August 1986 (Burges, 1986). Linsley Award winners, Vit Klemes, Peter Eagleson, Wilfried Brutsaert, David Pilgrim, James Dooge, and David Dawdy contributed papers to that special issue. Ray Linsley contributed a paper "Flood estimates: how good are they?" It is my privilege to know each personally and to have learned much from them. The nineteen authors of that defining set of fifteen papers gave us much food for thought.

My latest effort was in 2003 in a book chapter on "Calibration of Watershed Models" (Burges, 2003). I have chosen to reproduce key parts from the summary of that work because the issues raised touch on so much of what we will need to do to move forward.

Key Issues in Hydrologic Process Representation, Modeling and Measurement

For most catchments, where there are no lakes, approximately 98 to 99% of the landform is the "hillslope". Renewed focus on process details in our models at the hillslope scale is needed:

- It is essential to get the details of water and energy balances right at the individual hillslope element before we can use any model for serious prediction applications.
- Include realistic actual flow paths and fluxes (not mathematically convenient ones).
- Make appropriate nested measurements within catchments from upland scales of a few, to a few tens of hectares, as well as scales of tens of km^2 to hundreds of km^2 to capture hillslope runoff signals.
- Address biases in measured point rainfall.
- Establish rain measuring networks (including disdrometers) that reduce wind influenced under catch and use those data to gain the most complete information we can from radar (or other remote observation devices) to describe spatial precipitation patterns.

Modeling has to be consistent with the measurement scale:

- Distributed modeling requires more than one "rain gauge" and one "streamflow measuring location" for other than extremely small areas.
- Increased emphases on measuring the vapor exchange with the atmosphere and with measuring recharge to ground water are needed.
- Renewed emphasis on data quality assurance and quality control is needed so we can propagate errors appropriately and with confidence.

"The overall objective in all this work is to sharpen considerably the measured and modeled mass and energy balances for catchments of all sizes. The data networks and models that have been adequate for most prediction of hydrologic extremes and forecasting and water and land use decision making, when there were fewer pressures on these resources, are no longer adequate for the needs of modern hydrology. Modern needs include hydrologically- and ecologically-based decision making and hydrologic hazard prediction for increasingly populated regions subject to flooding and drought." (from Burges, 2003)

Appendix A

STEPHEN J. BURGES, RECIPIENT

Final Remarks

It was my good fortune to have had the chance to work with Ray Linsley and to benefit from his wisdom. I have been privileged to have worked with excellent graduate student, post-doctoral, and visiting colleagues over more than three decades. I have had the good fortune to work and publish with colleagues, Carlos Alonso, Colin Brown, Derek Booth, Bob Charlson, Bithin Datta, Rich Horner, Kiyoshi Hoshi, Doug James, Jim Karr, Dennis Lettenmaier, Sally Schauman, Matthias Steiner, Jim Smith, Jery Stedinger, Haruya Tanakamaru, and Alan Gillespie. Many of my ideas have been improved over the years as a result of many long conversations with David Dawdy, Tom Dunne, David Freyberg, Ken Potter, John Schaake, and more recently, Bryson Bates. A younger group of exciting colleagues are most generous sharing thoughts with me. These include Ana Barros, Efi Foufoula-Georgiou, Rodger Grayson, Dave Goodrich, Marc Parlange, and Ross Woods. Wilf Brutsaert, Marshall Moss, Don Nielsen, and Soroosh Sorooshian have given generously of their time guiding me in professional and scientific society activities. University of Washington emeritus colleagues Colin Brown, Ron Nece, and the late Gene Richey served as my local mentors. My University of Washington colleague, Tim Larson, is an excellent sounding board for ideas. My heroes include all the Linsley Awardees. I have had the privilege of having had at least one long conversation with each of them. I am saddened that two of them, Bob Smith and Harold Thomas, are no longer alive. I am very much in debt to all these splendid colleagues and friends for what they have taught, and, in many cases continue to teach, me. My greatest debt is to my wife and best friend, Sylvia, whose unstinting support made it possible for me to follow my chosen intellectually rich professional path.

Appendix A

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