LANCE W. VAIL

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Hydrology Group
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Since joining Pacific Northwest National Laboratory in 1981, Mr. Vail has been involved in projects covering a diverse set of water related issues. His professional experience includes basic and applied research, regulatory compliance assessments, and project management. His areas of expertise cover a broad spectrum of areas related to water resources and the nexus of water and energy.

RESEARCH INTERESTS

- Water resource management
- Multiple objective tradeoff analysis in water resources
- Uncertainty analysis in water resources
- Advanced hydrologic process modeling
- Impacts of climate on water resources
- Linking simulation models with optimization methods to water resource problems
- Linkage of physical and biological models in fisheries management

EDUCATION

B.S.	Humboldt State University, environmental resources engineering	1979
M.S.	Montana State University, civil engineering	1982

PROFESSIONAL AFFILITATIONS

American Geophysical Union
American Society of Civil Engineers
American Water Resources Association
International Water Association

CURRENT PROJECTS

- ***Hydrological Environmental and Safety Reviews of Combined Construction and Operating Licenses Applications (COLA) for New Commercial Nuclear Plants***. Technical Resource Manager and Task Manager. Mr. Vail leads hydrology reviews for many of the ongoing COLA reviews and provides mentorship to other site reviews. Mr. Vail is currently leading the hydrology reviews for Calvert Cliffs, Bellefonte, Lee, North Anna, Vogtle, and Grand Gulf. Additionally, Mr. Vail is supervising staff on Levy, Harris, South Texas and Summer. These reviews include a diverse set of water resources considerations including: sustainable water management; conjunctive surface and water management; flooding from extreme precipitation and wave action; thermal impacts on fisheries; etc.

- ***Water and Energy Management for Agriculture in the Pacific Northwest.*** Principal Investigator. An adequate and reliable supply of water and electricity is essential to all modern societies. Nowhere in the United States is the connection between water and electricity more obvious than in the Pacific Northwest and in no sector of the Pacific Northwest's regional economy is this interdependence of water and electricity clearer than agriculture. Water is the driver that powers the region's vast hydropower resources. The agriculture sector is also a large consumer of the region's electrical power supply, spending over $150 million per year for electrical power to pump water alone. Water is also a valuable way to store energy. The effective capacitance of water as a power demand shifting resource means that significant demand-side and supply-side improvements in both water and energy resources are possible for sectors such as agriculture with its reliance on an adequate, affordable and reliable supply of both water and energy. While newly emerged technologies are available to dramatically improve water and energy management, institutional barriers have slowed the development of such conjunctive management systems. The vision of adaptive management has generally

failed to be realized in practical resource management due to limitations of information infrastructure and institutional constraints. Mr. Vail is developing an information management infrastructure that will improve the conjunctive management of water and energy for the agriculture sector.

PAST PROJECTS

- ***Electrical Infrastructure Operation Initiative.*** Co-Principal Investigator. This LRDR project made significant advances in three critical science challenges that currently obstruct the functioning of a "water and energy control room of the future". These challenges were the three key themes of this project. The three themes of this project were:
  Water budget characterization. Managing any resource requires knowledge of the amount of the resource, the distribution of the resource, the rates at which the resource will increase, decrease, or redistribute. By linking physically-based process models with remotely-sensed spatial data, this project demonstrated the ability to significantly improve the accuracy and reliability of water budget estimates.
  Water supply and demand forecasting. Resource management actions are based on an estimate of the current state of the resource and forecasts of the likely future state of the system. Forecasts, by their nature, are subject to a degree of uncertainty. By generating and providing to the decision making process large ensembles of streamflow and energy demand projections, the resource management paradigm will shift from one focused nearly exclusively on reducing uncertainty to one more focused on managing uncertainty. By creating ensembles of streamflow forecasts based physical process models uncertainty is addressed explicitly. Generation and management of large ensembles generally results in significant computational capabilities. This project demonstrated a viable approach to generating and managing large ensembles of hydrological forecasts.
  Water and energy optimization. Modern natural resource managers are constantly required to balance multiple, conflicting, incommensurate objectives in an environment characterized by high levels of uncertainty, varying data quality and availability, and competing models and approaches. In attempting to sift through the vast number of feasible management options it is generally infeasible to evaluate each possible action evaluated for each feasible conceptual model through exhaustive enumeration. Optimization techniques provide an intelligent process to sift through the set of possible options. Optimization for control of water and energy resources requires a cautious, probing, adaptive approach, the success of which depends upon improved understanding, predictive accuracy, and iterative performance assessment. This project demonstrated a novel optimization approach based on evolutionary computing methods.

- ***Hydrologic Site Safety, Reviews for Early Site Permits.*** Principal Investigator and Project Manager. Reviewed three applications for an Early Site Permit (ESP) submitted to the Nuclear Regulatory Commission. This project provided an independent assessment of hydrologic suitability of the proposed sites. Assessments include a broad range of considerations such as flooding, low water conditions, ice impacts, seiches, storm surge, and tsunamis.

- ***Water-related Environmental Reviews for Early Site Permits.*** Task Manager. Reviewed three applications for an Early Site Permit (ESP) submitted to the Nuclear Regulatory Commission. This task provided an independent assessment of the proposed sites environmental suitability. Assessments include a broad range of considerations such as water-use conflicts and changes in water quality.

- ***Snohomish Basin Characterization.*** Principal Investigator. Advanced distributed watershed models were applied to provide the Tulalip Tribes of Western Washington state a thorough understanding of the impacts of logging, development, and climate on the Snohomish River Basin.

- ***Acid Rain TMDL***. Principal Investigator and Technical Project Manager. The objective of this work assignment for Region II of the U.S. Environmental Protection Agency is to develop a preliminary assessment approach for TMDLs for pH impaired waters listed on the New York State Section 303(d) list. The intent is to enhance and further develop TMDL program capabilities by providing expertise in both acid deposition and TMDL development. The development of such an assessment approach requires that available models and data resources be reviewed. Systems engineering methods will be used in developing a conceptual model to ensure the relationships between models and data are fully understood. The assessment approach will be

tested on one or more representative watersheds to be determined in close coordination with EPA, NYSDEC and Battelle.

- ***Environmental Impact of License Renewal of Commercial Nuclear Power Plants.*** Contributor. Mr. Vail assesses the water use, water quality, and hydrologic impacts of license renewal for the Nuclear Regulatory Commission's NEPA process. He has performed this function for the following commercial nuclear plants: Calvert Cliffs, Oconee, Arkansas Nuclear One, and Hatch., McGuire, Catawba, North Anna, Robinson, Ginna, and St. Lucie

PAST PROJECTS

- ***Chehalis Basin Characterization.*** Principal Investigator and Project Manager. Advanced numerical modeling, and GIS methods were applied to assist the Corps of Engineers in characterizing the Chehalis Basin in Western Washington State. The Chehalis Basin is subject to frequent flooding. The native populations of anadramous fish have been stressed to adverse changes in habitat resulting from development and logging.

- ***Generic Environmental Impact Statement (GEIS) for Decommissioning Commercial Nuclear Power Plants.*** Contributor. Mr. Vail is providing expertise in the development of a GEIS for decommissioning of nuclear plants. He provides expertise on water use, water quality, and hydrologic impacts for the Nuclear Regulatory Commission.

- ***Impact of Climate on the Lower Yakima Basin***. Principal Investigator and Project Manager. The objective of this three-year EPA STAR Grant Project was to develop and demonstrate an integrated assessment of the impact of climate variability and climate change on a diverse set of interests in the Lower Yakima Valley in Central Washington State. Interests considered include: surface and groundwater supply, surface and groundwater quality, air quality, public health, farm and regional economics, and fisheries. The project considered the effectiveness of changes in land management (crop selection) and water management (reservoir operation) in adapting to an uncertain future climate. A diverse set of models was linked with an optimization procedure to ensure that the tradeoffs between various resource management objectives are clearly articulated.

- ***Use of NOAA's Seasonal Climate Forecast for Water Resource Management***. Task Manager of Reservoir Optimization Task. The objective of this NOAA funded project was to show the potential value of improved climate forecasts in managing surface water reservoirs for multiple objectives. Using a pareto genetic algorithm the reservoir operating rules were optimized to define the tradeoff curves for hydropower, flood control, and instream flow requirements in the Tennessee River basin. Changes in forecast reliability result in changes these tradeoffs and thereby express the value of such improved forecasts.

- ***Accelerated Climate Prediction Initiative.*** Task Manager of Water Resources and Habitat Task. This project will provide a limited, systematic assessment of the potential effects of anthropogenic climate change over the next half-century on water resources in the western United States. This objective was accomplished by "downscaling" the results of the global-scale simulations described above to the spatial and temporal resolution needed to drive impact assessment models. Downscaling is particularly important for the West, where topography is a dominant climate driver. An important aspect of the hydrology of almost all western rivers is water management. Other than a few headwater streams, the hydrology of most rivers in the west is strongly affected by water use, and artificial storage. Water management models were used to study the effect of reservoir operations and understand the implications of climate variability and change on the water resources of the west.

- ***Linking Physical and Biological Models***. Principal Investigator and Project Manager. The objective of this three-year Laboratory Directed Research and Development project to develop and demonstrate an integrated natural resource analysis framework. This framework: dramatically improves the ability to integrate physical and biological models, thereby encouraging the utilization of advanced process models; allows utilization of large, sparse, and distributed data sets (including model output); communicates high-level tradeoffs and their respective uncertainties; and assesses, communicates, and minimizes scales issues. During the first year a significant obstacle to successful linking of physical and biological models was identified to be the fundamental structural differences between such models. The pervasive vagueness of rules and the

multivaluedness associated with temporal/spatial upscaling, suggested an approach using "fuzzy methods". The second year of this project utilized a variety of fuzzy methods including: fuzzy arithmetic, fuzzy logic, fuzzy clustering, and adaptive neural fuzzy inference systems (ANFIS). A series of rules and a database from the Multispecies Framework Process were employed to test the various fuzzy methods. These rules and data are used to define aquatic habitat diversity in the Pacific Northwest. A tool called FuzzyHab was developed to estimate habitat diversity from a set of categorical statements about the environment. Each of these categorical statements is vaguely defined. Estimates for each categorical statement are derived from physical process models.

- ***Integrated Natural Resource Data System.*** Contributor. This project is to demonstrate INRDS. INRDS is an advanced, web-based environmental information system that will promote public understanding of natural resource management issues and assist planners and decision makers in accessing the most relevant information and analytical tools and evaluating the tradeoffs of alternate actions. http://inrds.pnl.gov

- ***Early Warning of El Niño Southern Oscillation (ENSO) Events for Regional Agriculture.*** Task Manager of Reservoir Optimization Task. This project is investigating the current predictability of interannual variability in climate conditions in the Pacific Northwest to determine whether and how early warning and seasonal climate forecasts by the Climate Prediction Center (CPC) of the National Oceanic and Atmospheric Administration (NOAA) forecasts can be used to reduce the vulnerability of irrigated agriculture to low water-availability conditions. The study is funded by a grant from the economics and Human Dimensions Program of the NOAA Office of Global Programs. The Economics and Human Dimensions program aims to improve our understanding of how social and economic systems are currently influenced by fluctuations in short-term climate (seasons to years), and how human behavior can be (or why it may not be) affected based on information about variability in the climate system.

- Impact of Reservoir Operating Strategies on Resident Fish - Mr. Vail has employed several models to assess the impact on resident fish species of a variety of reservoir operating strategies. This study was undertaken as part of the Columbia Basin System Operation Review process. Mr. Vail helped define the values and value measures of the Resident Fish Work Group.

- Multiobjective Optimization - Mr. Vail is the project manager of an effort to assess the multi-objective optimization needs of Bonneville Power Administration. Objectives include: hydropower, resident fish, anadramous fish, irrigation, flood control, wildlife, and navigation. Mr. Vail is developing definitions of the canonical mathematical form of each of these objectives. The resulting multiobjective statement will be used to define the required optimization tools.

- Integrated Environmental Monitoring Initiative - Mr. Vail is a co-principal investigator for the Integrated Environmental Monitoring Initiative. The objective of this initiative is to develop and demonstrate a comprehensive interdisciplinary methodology targeted to improve the effectiveness of environmental monitoring and restoration activities. This objective required comprehensive integration of monitoring regimes, analytical practices, design methodologies, and compliance needs.

- Coupled Simulation/Optimization of Ground Water Remediation - Mr. Vail developed a computer code that coupled a ground water flow model with an optimization procedure. The code was able to provide estimates of the pumping/injection rates that would mitigate or remove a plume at minimal cost.

- Simulation of Watershed Hydrologic Responses to Alternative Climates - Mr. Vail is the principal investigator of a project studying the impacts of global climate change on the hydrologic response of a watershed. The results of hydrologic simulations using distributed snowmelt and soil moisture accounting algorithms were graphically compared via video displays of daily simulated snow water equivalent, soil moisture, and runoff for the American River, Washington, which drains 204 square kilometers of the east slopes of the Cascade Mountains, Washington. Snow water equivalents and snowmelt were simulated using a simplified distributed temperature-index model augmented with seasonally estimated net solar radiation. A classification scheme was used to partition the empirical cumulative probability distributions of precipitation (rain plus melt) and a topographic index over the basin into groups of near-equal membership. Topographically-based soil moisture capacities were assumed for each class and were estimated via automated calibration methods using historical data. The simulated soil moisture and snow water accumulations for each class were geographically mapped

for visualization. Test of the effect of alternative, warmer climates on snow accumulation, the seasonal distribution of soil moisture, and runoff were conducted by adjusting historical (daily) temperature and precipitation and repeating the analysis.

- Pacific Northwest Climate Change Case Study - Water Resource Impacts - Mr. Vail is investigating the effects of global climate change on water resources of the Pacific Northwest. Spatially distributed snowmelt, soil moisture, and runoff models have been combined with a graphics visualization package to understand the changes in snowpack, soil moisture, and evapotranspiration over time. A weather classification scheme has been developed which estimates point precipitation as a function of large-scale atmospheric variables. This allows the synthesis of point precipitation given large-scale meteorological information as might be produced by GCM simulations. Orographic effects also have a significant role in defining climate at the watershed scale. Efforts are under way to develop a scientific basis to extend the sparse meteorological measurements basis to extend the sparse meteorological measurements available for any watershed to estimate the spatial distribution of precipitation, temperature, and wind speed within the watershed. A reservoir network model for the Columbia River Basin has been aggregated to fourteen nodes. This network model of the Columbia River Basin has been aggregated to fourteen nodes. This network model will be driven by a collection of index watersheds. A daily hydroclimatological data set has been developed to aid in the selection of index watersheds.

- Acid Rain Watershed Modeling Project - Mr. Vail directed hydrologic part of a study to evaluate and apply several coupled hydrology/geochemical codes that were developed to model the impact of acid rain on surface water chemistry. The project involved extensive behavior and sensitivity analyses of three coupled geochemical/hydrological simulation codes.

- Incineration at Sea - The objective of this project was to assess the impact of incinerating toxic waste at sea on the aquatic environment. Mr. Vail developed a model on an IBM-PC to estimate the concentration of contaminant in the ocean.

- Aquifer Thermal Energy Storage - The objective of this project was to develop and apply computer codes that would simulate the trade-offs between different management policies of an Aquifer Thermal Energy Storage system. Mr. Vail independently developed, validated, and applied several computer codes for this purpose.

- Flow and Fractured Media - The objective of this study is to develop a state-of-the-art predictive capability for flow and transport in saturated fractured media. Mr. Vail was responsible for implementing, modifying, and testing a computer code that models steady flow in permeable media with discrete fractures. Mr. Vail has also developed a computer code that models steady flow through fractures in an impermeable rock mass. The fractures can either be specified or generated via Monte Carlo Methods. This code was applied in an investigation of the potential impact of a nuclear meltdown on groundwater.

- Modeling Flow With Uncertainty in Hydraulic Parameters - The objective of this study is to develop a methodology to analyze the uncertainty in predicting piezometric surfaces caused by uncertainty in groundwater flow parameters. Mr. Vail developed a computer code that couple perturbation and finite-element techniques to estimate the mean and variance of the piezometric surface.

- Stripa Mine Hydrogeologic Characterization - The objective of this study was to perform three-dimensional simulations with the CFEST code for ground water flow at the Stripa Mine in Sweden. Mr. Vail was the Battelle project manager of this effort.

Book Chapter

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Formal Reports

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