Water Resources Research Institute
Annual Technical Report
FY 2001

Introduction

WATER PROBLEMS AND ISSUES OF OREGON

Major water-related problems in Oregon are related to use exceeding availability in numerous watersheds, flooding during winter storm events, water quality degradation of both surface and groundwater, and impacted streams resulting in reduced salmonid populations. During Fiscal Year 2001, Oregon also experienced a drought that reduced water levels in reservoirs around the state and fueled a major water conflict in the Klamath Basin.

Both water quality and quantity are of concern to the State of Oregon. This is particularly important because watersheds with salmon and related species listed as threatened or endangered under the Endangered Species Act cover 50 percent of Oregon and there are competing interests for water. Several hundred streams in Oregon are water quality limited because of high summertime temperatures. Water quality degradation also results primarily from non-point sources and increased temperature resulting from inadequate riparian zones. There are increasing water quality problems associated with agricultural and forestry chemicals.

As noted, a major issue in competition among water users during the past few years has been the allocation of increased streamflows and watershed enhancement efforts to reverse the declining fish stocks in the Pacific Northwest. This issue drew national attention to Oregons Klamath Basin this year. Drought conditions forced the Bureau of Land Management to limit water withdrawals for irrigation in order to protect two endangered fish species. The decision caused economic hardship for area farmers and triggered a national debate over the endangered species act and the role of science in natural resources decision making.

Efforts to protect endangered salmon stocks have also raised questions about the impact of dams on Oregons rivers. Water supply throughout Oregon is regulated by an extensive network of storage reservoirs primarily built for flood control. Dams on the Columbia and Snake Rivers are major generators of electrical power and support a rapidly growing population and economy. Many natural resource experts are beginning to challenge the compatibility of the dam/reservoir systems and natural salmon populations. Since access to salmon harvests is protected by treaties between the US government and various tribes, many water use issues will be controlled by outcomes of complex legal battles.

Water resource management activities such as water rights adjudication, groundwater resources assessment, contaminated water and soil remediation, and interdisciplinary multi-focus planning are continuing. However, these efforts both within the State and through CWESt do not meet all the demands placed on the States water resources. Inadequate information is available on both quantity and quality of water resources, and the use of water resources to meet various demands.

Better management will require a more complete base of information and greater public involvement. Several imaginative processes have been adopted in Oregon to meet these needs. The Oregon Watershed Enhancement Board (OWEB) has mobilized considerable local activity directed to specific watershed improvements for communities. CWESt is helping supporting the public efforts by hosting workshops and developing proposals to address water information needs in Oregon and supporting watershed councils with technical expertise and information.

Surface and groundwater withdrawals and total water consumption are rising steadily driven by Oregons population and economic growth. Water competition and threats to environmental quality have become increasing critical. Increased efforts need to be made to protect, conserve, recycle, and develop production systems with fewer negative externalities. The need for expanded municipal water supplies has become a major political issue.

Beyond the high-public-attention areas of water policy and management, important unsolved technical questions related to water resource management remain unanswered. The main problem areas and specific problems identified by the CWESt include: -Inadequate seasonal instream flows (adverse effects on aquatic habitat, waste dilution and assimilation, recreation, downstream needs); -Contamination of ground and surface waters (sources, control, cleanup, protection of drinking water supplies); -Declining groundwater levels (poor knowledge of aquifer conditions, excessive withdrawals, need for management); -Management for grazing to protect streams in rangelands; -Inefficiency of water use (agriculture, industry, municipal and domestic systems); -Inter-connectivity of surface waters and groundwater (inter-connectedness, joint management, water yield, interstate use); -Deterioration and loss of aquatic/riparian habitat, especially wetlands; -High summer temperatures in streams that are habitat for cold water fish; -Management for protection of forested streams; -Protection of bay, estuarine and wetland resources (processes, impacts of nearby development); -Structural and non-structural options for water management (reservoir impacts, alternatives, seasonal and geographic problems, floods, water shortages, land use, management); -Competition for available water (shifting priorities, alternative sources, valuation); -Planning and management for water-related resources (implementation of state-of-the-art technologies and methodologies); -Effect of long term global weather patterns on water resource management in Oregon; -Water institutions and institutional arrangements (laws, rights, pricing, reuse, competition); and -Technology/information transfer to effectively disseminate information from researchers to users.

PROGRAM GOALS AND PRIORITIES

The Centers overall long-range goal is to assist in the sound management, sustained use, and protection of the States waters and water-dependent resources. Specific long-range goals of CWESt are to analyze and clarify the major water resources problems and issues in the state, and help to solve these problems through research, education, and technology transfer activities.

The objectives of the Center for Water and Environmental Sustainability, similar to those originally formulated in 1959, are to:

-understand Oregons current and future water resource needs; -identify areas where research, education, and technology transfer are required; -assure recognition of capabilities of water resources research and education; -initiate multidisciplinary research in areas of need; -provide information on water resources to decision makers through reports and workshops; and -promote and support multi-disciplinary graduate education programs in water resources.

Water resources problems in Oregon have quantity, quality, ecological, economic, institutional and social aspects. Therefore, the physical, biological, socio-economic and related sciences are all viewed as essential contributors to solutions of these problems. The Center activities emphasize multi-disciplinary, problem-oriented research and encourage interdisciplinary activities in support of that research.

Priorities

CWESt periodically establishes research priorities for solving critical water-related problems. Research priorities are set for both State and regional needs and have served to guide the development of the FY 2001 program.

The FY 2001 Center for Water and Environmental Sustainability Program has focused on protection of surface water and groundwater. The Water Resources program focused on research, education, and outreach related to protecting streams and wetlands for aquatic habitat interests. The Groundwater Cleanup and Hazardous Substance Outreach Programs focused upon research, education, and technical outreach regarding groundwater protection and remediation. The Sustainable University program focused on providing an inventory of Oregon State Universitys resource use and environmental impact. It also provided advice to the State of Oregon government on sustainability issues.

The projects included in the FY 2001 CWESt Program all addressed issues related to the Oregon and Pacific Northwest CWESt technical transfer plans. Several are high-public attention issues and relate to problems that continue to receive legislative attention.

The USDI Water Resources Research Institutes program has been of utmost importance in maintaining an active multi-disciplinary, problem-solving water research program in Oregon. The USDI program is also an important catalyst for initial contacts for water research by federal and state agencies, and for bringing research to the university campuses and the academic departments.

Research Program

Investigation of Groundwater Recharge and Agricultural Runoff Through the Willamette Silt, Oregon

Basic Information

Title:	Investigation of Groundwater Recharge and Agricultural Runoff Through the Willamette Silt, Oregon
Project Number:	2001OR10B
Start Date:	3/1/2001
End Date:	2/28/2003
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Nitrate Contamination, Management and Planning
Descriptors:	groundwater, Willametter Valley
Principal Investigators:	Roy Haggerty

Publication

1. Iverson, J., 2002, Investigation of the Hydraulic, Physical, and Chemical Buffering Capacity of Missoula Flood Deposits for Water Quality and Supply in the Willamette Valley of Oregon, MS Thesis, Oregon State University, Corvallis, Oregon, 147 p.
2. Iverson, J., and R. Haggerty, 2002, Investigation of the Hydraulic, Physical, and Chemical Buffering Capacity of Missoula Flood Deposits for Water Quality and Supply in the Willamette Valley of Oregon, Geological Society of America Cordilleran Section 98th Annual Meeting Abstracts with Programs 34(5), A-109.
3. Iverson, J., and R. Haggerty, Hydraulic Buffering Capacity of a Semi-Confining Unit for Water Quality and Supply in the Willamette Valley of Oregon, to be submitted to Ground Water.

Problem and Research Objectives:

The Willamette Silt provides two functions critical to Willamette Valley water supply: (1) the low hydraulic conductivity and reducing conditions of the Willamette Silt provide a protective barrier to agricultural contamination of the underlying aquifers; and (2) the Willamette Silt acts as a semi-confining unit to the Willamette Aquifer, and thereby reduces overdraft of streams by pumping wells. Unfortunately, the physical and chemical nature of this barrier is very poorly characterized or understood. In fact no comprehensive hydrogeologic or geochemical study of the Willamette Silt has ever been conducted.

The Willamette Silt is the most extensive geologic unit exposed at the surface in the Willamette Valley of Oregon, underlying the majority of the Central and Southern Willamette Valley's arable land. It covers an area of 3100 km^2 (1200 mi^2), virtually all of which either are currently under agricultural production, or are suitable for agricultural production. Over its entire extent, the Willamette Silt immediately overlies an important regional aquifer, the Willamette Aquifer. The Willamette Silt also lies above a second important regional aquifer, the Columbia River Basalt. In areas covered by the Willamette Silt, these two aquifers produce approximately 200,000 acre-ft per year (250,000,000 m^3/yr) of water, which is 60% of the Willamette Valley's groundwater production. All of the streams and rivers in the Willamette lowland except the Willamette River bottom in the Willamette Silt.

The goal of our study was to obtain direct information on recharge and transport of agricultural chemicals across the Willamette Silt. Specifically, we intended (1) to directly measure transport rates across the Willamette Silt; (2) to characterize the hydraulic connectivity between a stream bottoming in the Willamette Silt and the Willamette Aquifer in the presence of pumping stresses; (3) to quantify the nitrate and phosphate concentrations across the Willamette Silt, along with a suite of associated ions and cations. Goals 2 and 3 were successfully reached, while the first goal was not reached.

Methods, Procedures, and Facilities:

Our study was conducted at a field site approximately one mile SW of Mt. Angel, Oregon, along the Pudding River. The Pudding River is deeply entrenched within the Willamette Silt at this location. The field where the majority of the work took place has been variously cropped in corn, clover and cereal grains from 1945 to 1982, and then onions, seed cabbage, bush beans and flower seeds to 1996. Since 1997 the field has been used to run a wholesale in-ground nursery operation. Details of the field site and fertilizer applications are given in *Iverson* (2002) and on the project web site.

At the field site, three locations with a total of seven boreholes were drilled into the Willamette Silt and upper Willamette Aquifer along a transect across the Pudding River. Core samples were taken in six of the boreholes, including a total of 32 m (105 ft) of continuous core. Samples were frozen on site in dry ice. Piezometers, screened at the bottom 79 cm (2.6 ft), were installed in all boreholes. Two push-point piezometers were also installed below the River at two different depths. Piezometers were developed and instrumented with pressure transducers connected to data loggers. A tipping bucket rain gauge was installed at the site and connected to one of the data loggers. A flow meter was installed in the out-flow for the tile drain. A pumping

well screened within the upper Willamette Aquifer that lies within our piezometer transect and that is used for irrigation water supply was also monitored periodically.

Core samples from boreholes were analyzed for pH, phosphorus, ammonia, nitrogen as nitrate, sulfate, and a cation suite (total K, Ca, Mg, Na, Zn, Mn, Cu, and Fe). A further set of shallow test holes, traversing the same line as the piezometers, were dug to obtain more samples which were analyzed for the same chemical suite.

Water samples were taken from the Pudding River every 3.5 days from April, 2001 through February, 2002. Every other sample (i.e., weekly) was analyzed for total Kjeldahl N, total phosphorus, phosphorus as phosphate, nitrogen as nitrate, Cl, and sulfate. In two months (May and July), some samples are missing, due to equipment delivery dates and an equipment failure. While we intended to sample for 52 weeks, we sampled for less once we realized that the direct measurement of recharge across the Willamette Silt would not be possible.

Sediment cores were taken from the Pudding River near the beginning of each month from June, 2001 to November, 2001. We had originally planned to sample from the Hook Rd. bridge, making sampling possible through high water. However, we were unable to apply sufficient force through the sampler over the distance from the bridge to the sediment. Consequently, all samples were taken by wading into the water with soil coring equipment. Samples after early November were therefore not possible due to high water levels. Sediment samples were analyzed at depth intervals of 2 cm for nitrogen as nitrate, sulfate, Cl, and total Kjeldahl nitrogen.

A 3-day pump test was conducted at the irrigation well within our piezometer transect. The irrigation well, all seven of our bored piezometers, and five additional wells located within 1.4 km (0.9 mi) of the pumping well were monitored with pressure transducers and data logging equipment. The pump tests provided an average hydraulic conductivity and specific storage for the Willamette Aquifer. Through modeling we conducted later, the pump test also provided an approximate, vertically-averaged value of hydraulic conductivity for the Willamette Silt and uppermost Willamette Aquifer. Slug tests were also conducted at each of the piezometers, providing near-field values of hydraulic conductivity.

Eight samples of the Willamette Silt were analyzed in our laboratory for various properties, including hydraulic conductivity, grain size, and porosity.

A three-dimensional groundwater flow model of the field site was constructed using MODFLOW to analyze the stream-aquifer connectivity and to more fully analyze the pump test data.

Principal Findings and Significance:

The project has been successful at characterizing the hydraulic properties of the Willamette Silt and advancing our understanding of the hydraulic connection between streams that bottom in the Willamette Silt and the Willamette Aquifer. We have also significantly advanced our knowledge of the potential for agricultural leachate to cross the Willamette Silt and contaminate the Willamette Aquifer. The major findings of this study are outlined below. Other findings are described in *Iverson* (2002).

(1) Field observations of nitrate penetration fronts provide evidence that, at our field site near Mt. Angel, Oregon, the Willamette Silt currently prevents transport of nitrate to the Willamette Aquifer. A general trend of decreasing nitrate with depth is observed at two sites near the Pudding River. Further, the point at which nitrate concentrations go to background levels,

between 7.5 and 9 m bgs (25 and 30 ft bgs), is coincident with a reduction-oxidation (RedOx) boundary which also corresponds to a sharp rise in pH with depth. This RedOx boundary is easily seen in core sample and is defined by a sharp transition from red-brown silt (oxidized) to blue-gray silt (reduced). We hypothesize that autotrophic denitrification is taking place at this boundary.

It is important to note, however, that it is not yet known the extent to which the Willamette Silt prevents nitrate transport elsewhere in the Willamette Valley. Additional research is needed to map the presence of the RedOx boundary and the thickness of the Willamette Silt below the RedOx boundary over the rest of the Valley. We also do not know whether the RedOx boundary is moving downward. If it is moving downward and if the rate of movement is influenced by fertilizer application, then future nitrate contamination of the Willamette Aquifer by nitrate may be possible.

(2) Pumping from the Willamette Aquifer has a minimal effect on streams that bottom in the Willamette Silt. Numerical analysis, supported by pump-tests, slug-tests, and lab measurements of hydraulic conductivity, show that the Willamette Silt is a source of diffuse recharge (as opposed to focussed recharge underneath surface water bodies). This diffuse recharge accounted for more than 98% of the water volume removed from the Willamette Aquifer during a 3-day pump test. Less than 1% of the volume of water removed from the Aquifer at a pumping well located less than 200 ft from the Pudding River was recharged to the Willamette Silt from the River. The Willamette Silt acts as a reservoir, accepting water during the wet winter months, and diffusely recharging that water to the Willamette Aquifer throughout the year. Consequently, the predominant net effect of pumping from the Willamette Aquifer far from the Willamette River is likely to reduce winter flows in streams.

(3) Laboratory measurements of hydraulic conductivity indicate that at our field site the harmonic mean vertical hydraulic conductivity of the Willamette Silt is approximately 2×10^{-7} m/s (0.5 gal/day/ft^2). Slug tests in shallow to intermediate wells within the Silt and with good completion provide estimates of hydraulic conductivity that are in approximate agreement. However, slug tests from wells completed at the top of the Willamette Aquifer and data from our pump tests suggest that the top of the Willamette Aquifer has lower hydraulic conductivity than the Willamette Silt, with values of approximately 1×10^{-9} m/s (0.002 gal/day/ft^2). This low value is probably due to cementation (visible in core and noticeable during drilling) of the gravels at the top of the Willamette Aquifer. Consequently, the hydraulic connection between the Willamette Aquifer and the Willamette Silt is lower than indicated by the hydraulic conductivity of the Silt.

While the project had these important findings and successes, the project was unsuccessful at directly measuring the rate of water movement across the Willamette Silt. This was the intended purpose of measuring concentrations of Cl and other ions in both the Pudding River and the underlying sediments. The concentration profile in the sediment was to be modeled, using the concentrations in the Pudding River as a boundary condition, to obtain a rate of transport down through the sediment. This failed because concentrations within the sediment did not show a coherent pattern related to the concentrations in the water above. We believe that this failure is due to a combination of (1) sediment movement; (2) hydraulic gradients in the sediment other than vertical; and (3) sediment-water interactions that modified the pore-water chemistry. An additional, though not fatal, problem was our inability to sample after November due to high water.

A web site has been created that provides access to all data (water chemistry, soil chemistry, head, physical properties, and hydraulic properties of the Willamette Silt) from the project, graphs of most of the data, well logs, and an electronic copy of Iverson (2002, MS thesis). The web site address is http://terra.geo.orst.edu/~haggertr/WS/

Training and publications:

This grant contributed to the training of four students.

Justin Iverson. Iverson completed his MS thesis, "Investigation of the Hydraulic, Physical, and Chemical Buffering Capacity of Missoula Flood Deposits for Water Quality and Supply in the Willamette Valley of Oregon", in April, 2002. This grant supported his research and his results are the primary results presented in this report.

Louis Arighi. Arighi began his MS, "Protection of the Willamette Aquifer Due to Attenuation of Nitrate by Unweathered Quaternary Sediments", in September, 2001. The first data sets for his thesis are provided by this grant.

Bruce Hammelman. Hammelman is an undergraduate student who has worked on the project from the beginning, collecting samples, building equipment, processing data, and building a web site.

Nghi Huynh. Huynh worked on this project during its inception in 2001. His primary role was an assistant during the building of equipment and the first data collection.

The grant resulted in one thesis and one abstract, and will result in one paper currently in preparation for submission.

Iverson, J., *Investigation of the Hydraulic, Physical, and Chemical Buffering Capacity of Missoula Flood Deposits for Water Quality and Supply in the Willamette Valley of Oregon*, MS Thesis, Oregon State University, Corvallis, Oreg., 147 p., 2002.

Iverson, J., and R. Haggerty, Investigation of the Hydraulic, Physical, and Chemical Buffering Capacity of Missoula Flood Deposits for Water Quality and Supply in the Willamette Valley of Oregon, *Geological Society of America Cordilleran Section 98th Annual Meeting Abstracts with Programs 34*(5), A-109, April, 2002.

Iverson, J., and R. Haggerty, Hydraulic Buffering Capacity of a Semi-Confining Unit for Water Quality and Supply in the Willamette Valley of Oregon, to be submitted to *Ground Water*.

US Transboundary Waters: Interstate Waters, Interstate Compacts

Basic Information

Title:	US Transboundary Waters: Interstate Waters, Interstate Compacts
Project Number:	2001OR11B
Start Date:	3/1/2001
End Date:	2/28/2002
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Management and Planning, None
Descriptors:	
Principal Investigators:	Aaron T. Wolf

Publication

Problem and Research Objectives:

There is an urgent need for an up-to-date and widely available spatial database in which information on the geopolitical and socioeconomic characteristics of watersheds that cross state or sectoral boundaries can be combined with current biophysical information to help predict and prevent potential conflict over water resources, or to resolve such disputes when they do occur. Such data can also aid in making land use and management decisions within watersheds that affect availability and quality of water.

To aid in research on the nature of conflict and the assessment of the process of water conflict resolution, we have been working over the past six and a half years to develop the Transboundary Freshwater Dispute Database (TFDD), a project of the Oregon State University Department of Geosciences, in collaboration with the Northwest Alliance for Computational Science and Engineering. In this context, "transboundary" refers both to water that flows across legal or political boundaries as well as to water and watershed resources used by more than one set of interests – i.e., water needed by the environmental as well as economic sectors.

While much of this data either has been or is in the process of being made web-accessible, recent research has allowed us to compile a vast amount of spatial information related to international rivers, which currently is only available off-line. Our two-year project, International Waters: Basins at Risk, required the accumulation and rendering in a unified format over 100 spatial layers in a global Geographic Information System. The data cross disciplinary and spatial boundaries, and include biophysical, socio-economic, and geopolitical categories. These data layers have been collected from sources around the world and put in a unified, ready-for-analysis format.

Research objective, for this project grant, was to continue developing our "virtual center" for the study of transboundary waters, by making accessible these data layers for web-based analysis, as follows:

1) Structuring three existing components of the Database. These component are a digitized base map of U.S. and international watersheds, an annotated bibliography of the "state of the art" of water disputes and dispute resolution, and a list of all U.S. interstate compacts and international treaties – such that a web user might use information from any component to get to any other component.
2) Investigating the possibilities of having web-based, interactive GIS analysis of our existing spatial data. Frankly, this could not be accomplished within the limitations of this current project, but other grants are pending which would allow for the implementation of what we find here. Although the infrastructure for the virtual center would be housed at Oregon State University, as a subset of the existing Transboundary Freshwater Dispute Database project, it would be developed in close collaboration with, and linked with partners across campus and around the world.

Specific activities, included:

- ◊ Updating all bibliographic and compact information, and integrate new data into existing databases
- ◊ Converting existing databases to web-ready formats and linking search capabilities to include both spatial and textual information
- ◊ Investigating possibilities of interactive GIS using ARCIMS or other as appropriate; and,
- ◊ Preparing for the launching of the new website, database components, including the U.S. components sponsored by this grant

Methods, Procedures, and Facilities:

Although our proposed use of spatial information is unique, our design architecture is not. This circumstance allows us to use existing tools and expertise to present the information to the web community. Using existing tools also shortens development time, allows us to capitalize on widely-available spatial information as well as our own in-house spatial coverages, and helps minimize costs. We want to invest in and use existing or proven technologies for building the infrastructure of the center, yet we work closely with existing technology vendors to provide feedback about practical applications of their products and foster interaction between vendors and real-world users.

One of the strengths of our web-based research tool is our plan to link the graphical map-based interface directly to an existing database of biophysical and environmental resource information. By combining the capabilities of data layering and database linking, a more specific example of our site goals can be understood. As an example, and only one of many possible options, a visitor to our site might:

- ◊ select a region of interest from a global map
- ◊ enlarge the selected region
- ◊ opt to display one or more layers (as an example, such layers might include political boundaries, rivers, population centers, basin or watershed boundaries, or areas covered by treaties)
- ◊ view and print more specific data related to specific layers
- ◊ link to additional resources available on the web.

Principal Findings and Significance:

- ◊ The web-based database of major U.S. watersheds is up and running. The map (see attached) will be linked to the Transboundary Freshwater Dispute Database (TFDD) website when the new TFDD site is launched (July-August 2002).
- ◊ The database of the U.S. interstate compacts is linked to this map.
- ◊ The annotated bibliography will be completed this month and will be linked to the map at that time.
- ◊ Excellent progress has made in displaying existing spatial data on the web. A spatial demonstration has been created, listing data on Climate, Population, Treaties, Events, Dam Runoff, and Water Stress. For each basin and indicator there is a pop-up window, displaying the data, along with a legend and source.
- ◊ The database has been put into a web-accessible format.

Continued expansion of the database includes:

- ◊ By the end of July, we hope to finish all continents with the above indicators (Climate, Population, Treaties, Events, Dam Runoff, and Water Stress).
- ◊ During the remainder of the summer, more indicators and Excel/Access information will be added, so researchers can download the data and do their own analysis.

Statement of Results or Benefits :

OSU has developed an online GIS of transboundary water indicators and annotated bibliography, going online July-August 2002. The treaty database has been expanded from 150 treaties and related agreements to presently having just over 400 treaties and related agreements, many with the full text of the agreement available online. The documents cover a range of years, regions, and basins. The expanded treaty database will be going on the web in summer 2002 with an improved user interface. The treaty database will be linked with the bibliography, event, biophysical, and socioeconomic data by an interactive map of basins, which will allow users to select information (from all the databases) by clicking on a map of that basin. Additional treaties will be added as they are obtained. Sometime this summer, please visit the new version of the database at http://www.transboundarywaters.orst.edu/

Training and publications:

Six OSU students have been intimately involved in creating and expanding the database over the last year – Sara Ashley, Brian Blankenspoor, Cathy Pearson, Shira Yoffe, Greg Fiske and Becci

Dale. The students performed a number of duties for the creating, maintaining, and upgrading the database, including: treaty coding; data gathering, organizing, cleaning, and entering; database design; access database design and development; creating site demonstrations, spatial data, and many of the maps used in the web display. Staff and faculty at OSU's Northwest Alliance for Computational Science and Engineering (NACSE) have been instrumental in putting the database into a web-accessible format. They also designed the website interface.

Information Transfer Program

Basic Information

Title:	Interactive Web Site for Streamflow Evaluations in Watershed & Habitat Restoration Planning
Start Date:	4/1/2001
End Date:	6/1/2002
Descriptors:	streamflow, hydrology, hydrologic evaluations, internet, databases, watershed assessment, habitat assessment
Principal Investigators:	Peter Klingeman

Publication

1. Bogavelli, Vaishali, 2002, Streamflow Research Web Site: General overview and detailed description of hydrologic analysis techniques included on the web site. Master of Science Report submitted to Civil, Construction and Environmental Engineering Department, Oregon State University.
2. Coles, Derron, 2002, Normalization of water-related projects in Oregon through development of a comprehensive web site. Master of Science Report submitted to Civil, Construction and Environmental Engineering Department, Oregon State University.

Problem and Research Objectives:

The Research Problem

All soundly-based stream projects require careful and often extensive use of streamflow data. Such data may be needed for several types of conventional hydrologic analyses, depending on the nature of the project and type of information sought. Oregon is committed to watershed enhancement and to salmon recovery. Pressures periodically arise to use streams for other purposes, including diversion for water supply or energy generation.

The need for hydrologic assistance is illustrated by a recent newspaper article (Corvallis Gazette-Times Feb. 2, 2001) describing efforts by a watershed council to address salmon habitat restoration and water quality enhancement, involving over $370,000 for projects. Notably absent from the article was discussion of any streamflow evaluations. Subsequent discussion (2/5/01) with the Council coordinator indicated that some assistance was provided a participant from a federal agency to make streamflow hydrologic and hydraulic assessments. However, the main emphasis was on determining flood peaks at culverts. For other projects, assistance in placement of "structures" in streams subject to risks from large flows was based mainly on guidance from fishery biologists, rather than hydraulic engineers or hydrologists. For certain projects, engineering help was hired. But most of the expenditures were made with only rudimentary hydrologic and hydraulic guidance. This is not an isolated situation, but rather is symptomatic of state-wide and regional efforts by volunteer local groups to try to address significant watershed/stream/ecosystem issues with limited financial resources and preferences to invest in on-the-ground activities. The proposed web-site project is intended to assist such groups and their technical partners by providing hydrologic guidance for making needed analyses.

A major problem facing watershed, habitat and water development projects is the inadequacy of gaging station records to provide site-specific information. For example, there are less than 50 gaging stations in operation to cover the streams draining the Coastal Range along the entire Oregon coast, an area of about 8,050 square miles. Most of the long-term records are for stations with large drainage basins. Thus, for a project on a small ungaged stream there is little hope of finding streamflow records from a nearby small stream with which to make comparisons.

Research Objectives

The proposed project involves finding ways to create an interactive web site for the assessment of streamflow characteristics in conjunction with watershed and habitat restoration planning. Initial development of the web site focuses on use with streams along the Oregon Coast, extending between the Columbia River and California and from the Coast Range crest to the Pacific Ocean. Subsequent steps are geared to generalizing methods so that the geographic region may be expanded by users to other parts of Oregon.

The specific objectives of the project are to:

1. Learn web-site construction and use basics, map display techniques, and the requirements for developing the interactive use of a web site.
2. Develop and refine pertinent conventional hydrologic analyses into step-by-step formats for use by knowledgeable individuals without special or advanced training.
3. Incorporate these hydrologic analyses into the web site pages, along with an easy-to-use tutorial for users.
4. Assemble a list of the sources for pertinent hydrologic data into a table with links, with reference to specific river basins.
5. Assemble a table of streamflow gages for chosen river basins, with links to data on USGS web sites, beginning with the three Oregon coastal basins.
6. Perform statistical analyses of the hydrologic data for each of Oregon's 18 major drainage basins and provide estimations for drainage area, mean annual precipitation, typical monthly flow as a percentage of mean annual flow, and mean annual flow per unit of drainage area for each of these 18 basins.
7. Test the developed methods with selected individuals who have hydrologic skills.
8. Make the developed web site information available to a wide user group.

Methods, Procedures, and Facilities:

The OSU-WRRI participated in a regional study of low-head hydropower potential in the Columbia River Basin with the Water Research Institutes of Washington, Idaho and Montana, leading to reports WRRI-61 (with 18 data appendices for the 18 OWRD basins in Oregon) in 1979 and WRRI-62 (with 1 data appendix) in 1980. Work was done on large mainframe computers at the four participating universities. These allowed users to determine mean flows, monthly flows, flow duration curves, and low-head hydropower potentials for points along more than 6,700 miles of streams in Oregon, as well as for thousands of miles of streams in other parts of the Columbia River basin. The methodology has also been used over the past decade by various groups of Oregon State University students in CE 543 Applied Hydrology to refine and expand such analyses for particular basins (North Coast, Mid-Coast, South Coast, John Day, and Umatilla). The CE 543 work was done on PCs using spreadsheet techniques. These related research activities form the methodological basis for the project conducted here.

The specific project methods and procedures were as follows:

1. Learn web-site "how-to-do-it basics."
2. Learn the requirements for developing the interactive use of a web site.
3. Develop and refine the ways for incorporating conventional hydrologic analyses into a straight-forward step-by-step format so that knowledgeable individuals may easily obtain hydrologic information without special or advanced training in hydrology.
4. Assemble a table that lists all active USGS stream gages on Oregon coastal streams, with links that take the user directly to the desired streamflow data.
5. Add links to other data sets and give instructions for acquiring and new data as it becomes available at the end of each water year, and for modifying the analyses accordingly.
6. Test the developed methods with OSU graduate students, an OWRD hydrologist, a USGS hydrologist, a USDA-NRCS hydrologist, and an OSU Extension Service representative.
7. Provide illustrations for the use of the web site to assess streamflow characteristics for such applications as (1) stream habitat projects, particularly for EAS-listed species, (2) energy generation projects, (3) water supply projects, and (4) culvert evaluations.
8. Make improvements in the use of the web site, based on experience gained from testing.
9. Promote the use of the developed web site by providing information on the site and its use to the Oregon State University Cooperative Extension, the Oregon Watershed Enhancement Board, its various watershed councils (about 90 presently function), federal and state agencies, and consulting firms that provide hydrologic services.

The facilities used were PC computers available in the Civil, Construction and Environmental Engineering Department.

Principal Findings and Significance:

Principal Results

Because the goal of the web site is to guide individuals through hydrologic analyses of projects, it was imperative to create an appropriate layout that makes navigation intuitive. We decided to construct the web site with the logical steps of conducting a water related project in mind. Those project steps typically include: (1) collecting preliminary information on the project site, (2) compiling analysis techniques that will be used to facilitate project decisions, (3) performing analyses, (4) interpreting the results, and (5) implementing a design based on the results.

The web site is separated into eight sub-sections, as shown in Figure 1 below. Going in a clockwise direction through the figure, the right half of the circle addresses the project steps mentioned above. The left half of the circle contains information to help make navigating the site straightforward and to smooth the learning process.

Figure 2 gives an idea of how each of the sub-sections relates to the outlined procedures. As shown in Figure 2, each of the procedures is addressed by at least one subsection of the web site. The information provided in each subsection is listed in Table 1.

At this point, we have tested the layout of the web site through two water resources engineering graduate students and two water resources engineering professionals. We have received positive feedback stating that the configuration of information on the site is logical and easy to follow. Also, we have reorganized the data collection portion of the web site according to suggestions made by said participants.

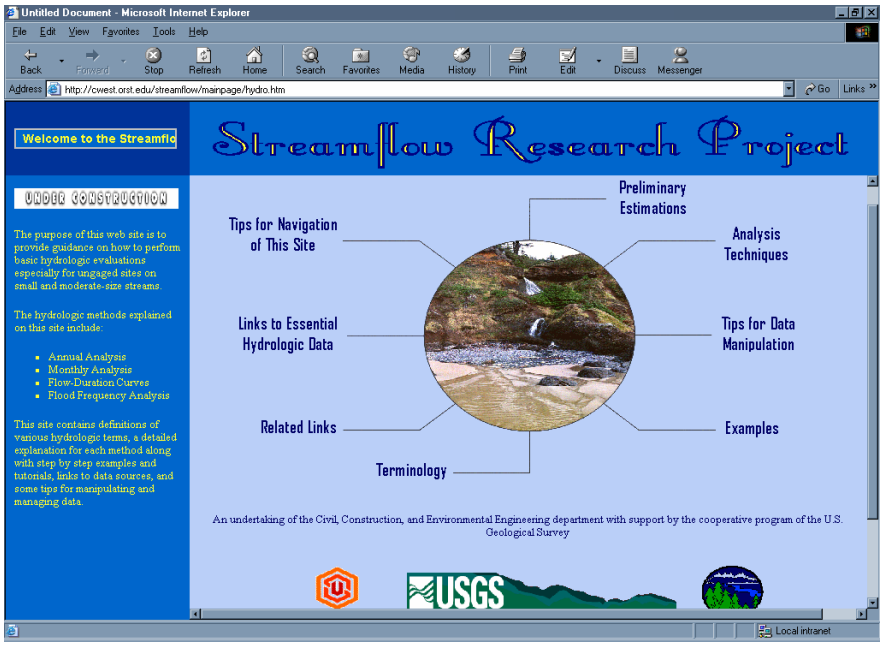

Figure 1: Main page of the Streamflow Research Project web site

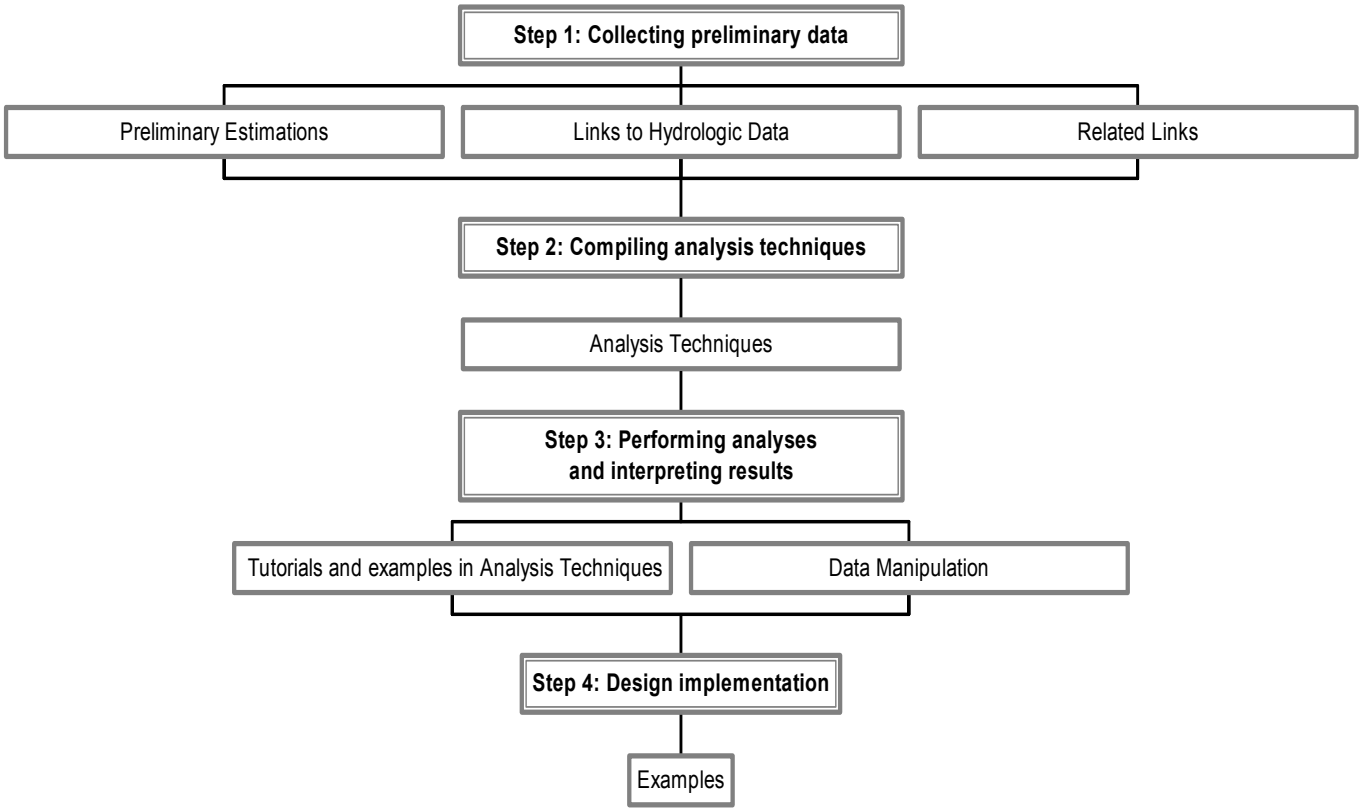

Figure 2: Typical project procedure and associated web site sub-sections

Table 1: Information for project procedures provided by web site subsections

SUBSECTION	RELATED PROCEDURE	INFORMATION PROVIDED
Preliminary Estimations	Collecting preliminary information	Values are provided for ▪ Discharge per sq. mile for Oregon watersheds ▪ Annual precipitation estimations for Oregon ▪ Percentage of annual flow for each month for Oregon watersheds
Analysis Techniques	Compiling analysis techniques and performing analyses	Definition and explanation of how to conduct ▪ Annual analyses ▪ Monthly analyses ▪ Flow duration/Exceedance Probability Analyses ▪ Flood frequency analyses
Tips for Data Manipulation	Performing analyses	▪ How to copy data ▪ How to perform time conversions on data ▪ Spreadsheet tutorial
Examples	Design implementation	Examples of completed analyses and conclusions for hypothetical water projects
Tips for navigation of this site	N/A	Explanation of the sub-sections and layout of the web site
Links to Essential Hydrologic Data	Collecting preliminary information	Links to streamflow and precipitation data for Oregon
Related Links	Collecting preliminary information	Links to hydrology related data such as meteorological, snow pack, and fish data
Terminology	N/A	Definitions of relevant terms

Significance of Project

It is expected that a person or group (e.g., watershed council) will be able to access the web site and work through a series of steps in order to develop hydrologic information for a project. This information would provide a basis for conducting a feasibility evaluation for the project, as well as for deciding whether more extensive data should be collected at the project site to improve the feasibility evaluation. Such evaluations are routinely needed for dozens of projects in Oregon each year, particularly to help determine whether these projects can be expected to realistically meet streamflow-related expectations.

The project results provide a straightforward step-by-step process for conducting hydrologic assessments of projects. The user would first begin by determining the geographical location of the project stream on a reference map and the topographic boundaries of the drainage basin. From the boundaries, the value for corresponding drainage area of the basin above the project site may be determined. The user is then able to work through the web page process. It is initially necessary to identify an appropriate streamflow gage from the web-page station list and location map. The user then follows the methods outlined on the web site to determine: (1) locations of nearby gaging stations, (2) sources for the data from those stations, (3) estimated long-term mean annual flow at the site, (4) estimated long-term mean monthly flows for each month, (5) variability of these 13 month-characterizing values (their standard deviations and extremes), (6) long-term patterns of past wet and dry periods, (7) flow-duration curve for mean daily flows, (8) and flood

magnitudes and frequencies of occurrence. Thus, the user should be able to develop a set of hydrologic estimates of streamflow conditions and have access to the original data for validation and other purposes.

Results from this project will also provide a basis for training in web-site techniques and hydrologic applications for future students. Members of the OSU Cooperative Extension Service will receive special instruction in use of the web site, as they are likely to interact directly with many potential users.

Training and publications:

This type of activity has been used in the course CE 543 Applied Hydrology several times in recent years. Each class contained 10-20 graduate students (MS, PhD, special -- from Civil, Construction and Environmental Engineering Dept.; Bioresources Engineering Dept.; Forest Engineering Dept.; Forest Sciences Dept., Geosciences dept.; Environmental Sciences Dept., etc.) who received training in the data workup methodology.

Direct training support on this project was provided for two graduate students. They worked on this project full time for most of summer 2001 and at a reduced commitment during the 2001-2002 school year while they completed coursework for the MS degree. They were previously involved in development of portions of the CE543 date base for the Oregon coast and were thus familiar with the hydrologic methods involved in this project. Primary training efforts focused on learning web page design techniques, data manipulation, and graphics development. It was critical to learn how to establish a user-friendly web site and how to assemble extensive databases. Training further included determining how to make improvements in the previously-used analytical schemes so as to make them more user-friendly for people who have not taken graduate coursework in hydrology.

Two publications are in progress of completion as of this report:

1. Bogavelli, Shali. 2002. Streamflow Research Web Site: General overview and detailed description of hydrologic analysis techniques included on the web site. Master of Science Report submitted to Civil, Construction and Environmental Engineering Department, Oregon State University. (expected completion in July 2002)
2. Coles, Derron. 2002. Normalization of water-related projects in Oregon through development of a comprehensive web site. Master of Science Report submitted to Civil, Construction and Environmental Engineering Department, Oregon State University. (expected completion in July 2002)

Basic Information

Title:	Web-based Data Analysis and Distribution Technology for Watershed Datasets
Start Date:	3/1/2001
End Date:	2/28/2002
Descriptors:	GIS, data distribution, world wide web, watershed planning
Principal Investigators:	John Bolte

Publication

Problem and Research objectives:

As watershed planning is becoming increasingly important for implementation of the Oregon Plan for salmon recovery, the Willamette Restoration Initiative, response to endangered species listing, Clean Water Act requirements and other activities. Science-based planning requires access to data, in a way that presents that data in a format that is both readily accessible and in forms that are readily utilized by policymakers and stakeholders. Various watershed-scale datasets are also integral to the development of watershed assessments developed by watershed councils using the Oregon Watershed Enhancement Board's (OWEB) Watershed Assessment manual, which prescribes specific datasets and reporting requirements necessary for completion of a watershed assessment.

Technology has progressed to the point where the development of dataset storage and delivery mechanism is feasible. The Internet provides the necessary access and delivery mechanism, and is generally available to a wide audience. Additionally server-based software has made the presentation and download of datasets on the web realistic. There is a need to develop this technology specifically for the delivery of watershed council-oriented dataset access.

Methods, Procedures, and Facilities:

Web-based data analysis and distribution require the following components:

A data server and associated disc storage;
Server software providing access to and display of non-spatial datasets;
Server software providing access to and display of spatial (GIS) datasets.

Data server: We host the datasets and associated web pages on biosys.bre.orst.edu, a machine physically located with the Bioengineering Department at Oregon State University. It is a Windows 2000 server machine with 30 GB of data storage and the usual backup/power protection, etc. capabilities. Data is backed up daily on tape and to a redundant remote storage unit. The server hosts spatial and non-spatial data servers.

Server Software for non-spatial datasets: We have extensively reviewed Web-based server software for nonspatial databases, and have found Allaire's Cold Fusion Application server to be an effective, capable, and robust server. Cold Fusion is cross platform, running on both on NT Server and Unix OS's. An additional advantage of Cold Fusion is that Cold Fusion applications currently can run on OSU's main web server (osu.orst.edu), so applications are portable between NT and Unix hosts. Additionally, over the past several years we have written a large body of data access code employing Cold Fusion that has been leveraged into this effort.

Server Software for spatial datasets: Many of the datasets useful for watershed analysis are GIS-based. Depending on the form of the data (shape file, Arc Coverages, etc.) a data access server like Cold Fusion may or may not be appropriate. Cold

Fusion does not provide map display or browsing capabilities, so we use ESRI's Internet Map Server to host map-based data.

Principal findings and significance:

The project has been successful at creating a prototype site hosting a number of different types of watershed-related data. The basic technology approach combining basic HTML-based web interfaces, Cold Fusion-based database access, and Internet Map Server-based map serving, has been successful at providing this data on the web. Additionally development is needed before the site can be fully functional, but the prototype site has been useful as a vehicle for providing basic database access and map serving methodologies.

We have developed a number of watershed datasets that area available through the web site. These include roads, streams, vegetation, hydrology, sediment transport capabilities, and many others (see http://waterconnection.orst.edu for a complete list of coverages.).

A second source of data is being hosted as well. We have gathered photos of various watershed "problem areas" and restoration options. These are general in digital format, in anticipation of making them available on the web. A database framework for storing photo related information, with keywords, for retrieval and display on the web, is included in the technology package delivered in this project, populated initially with these restoration-oriented photos.

Our primary target is stakeholder groups, particularly watershed councils, and we have worked with two councils to develop user interfaces and analysis requirements. However, because all data is public and downloadable, any user has access to the datasets.

Training and publications:

A graduate student has been involved in this project at the masters degree level.

Basic Information

Title:	104B Adminstrative and Information Transfer Activities
Start Date:	3/1/2001
End Date:	2/28/2002
Descriptors:	conferences, technology transfer, education
Principal Investigators:	Kenneth Williamson, Denise Lach

Publication

1. Brent, Steel, Denise Lach, Peter List, and Bruce Shindler. 2001. "The Role of Scientists in Natural Resource and Environmental Policy Processes: A Comparison of Canadian and American Publics. Journal of Environmental Systems: 28(2): 135-157.
2. Williamson, K., (with M.F. Azizian, P.O. Nelson, and P. Thayumanavan), 2001, "Environmental Impact of Crumb Rubber Asphalt Concrete Leachate Contaminants from Highway Construction and Repair Materials on Surface and Ground Waters,", American Chemical Society, Environmental Chemistry Division, Vol. 41, No. 1, pp. 409-413, 2001.

CWESt Administration and Information Transfer Activities

CWESt sponsored, attended, and presented at several seminar series and workshops, maintained water resource education websites, and promoted several water resource education programs. Many projects and activities received supplemental funding in addition to the Water Resources Institute Base Grant. When outside funding was received, sources are noted below.

Outreach, Education, and training Activities

CWESt participated in and sponsored several conferences, workshops, and planning meetings at local, statewide, regional, and national levels. These activities were a joint effort by the Director, Ken Williamson; Co-Director, Denise Lach; Program Coordinator, Stephanie Sanford; the Technology Transfer Coordinator, Maria Panfil Wright; Public Health Liaison, Anna Harding; Technical Outreach Specialists, Michael Fernandez and Terry Brock, in addition to cooperation from other faculty members. CWESt successfully sponsored and co-sponsored the following conferences, seminars and workshops.

Conferences

Co-sponsor, ***Oregon Sustainability Forum***, Portland, OR, September 2001. CWESt organized the two-day "Education" track and sponsored a meeting with Second Nature and Oregon universities and colleges to begin discussions about forming a West Coast University Sustainability Consortium.

Co-sponsor, Oregon ***Brownfields Conference, "Bright Ideas for Redevelopment"***, Bend, Oregon September 25-26, 2001. Brownfields are properties where redevelopment is complicated by actual or perceived contamination. This conference brought together economic development professionals, local government officials, environmental consultants, attorneys, and federal and state government representatives to discuss issues related to the assessment, cleanup, and redevelopment of brownfields. Approximately 120 people participated in this event co-sponsored by CWESt, Oregon Department of Environmental Quality, and the Oregon Economic and Community Development Department.

Co-sponsor, ***James Vomocil Water Quality Conference***, Corvallis, OR, November 2001. The annual Vomocil Water Quality Conference at OSU is designed to bring scientists, regulators, agricultural producers, landowners and concerned citizens into conversation about water quality management and research in Oregon. At this year's conference CWESt organized a Klamath Basin Symposium that provided a forum for education and information exchange about the region's water-conflict between irrigation and fisheries needs. The session's panel included a fisheries biologist, tribal member, farmer, extension agent, and water lawyer. It was attended by approximately 150 people representing state and local agencies, universities, private sector, students, and land owners. The Vomocil Conference is an annual event sponsored by CWESt and the OSU Extension Service.

Co-sponsor, ***TOSC-TAB/EPA National Conference***, Portland, OR, January 2002. This conference brought together EPA Community Involvement Staff and personnel from five

regional Technical Outreach Services to Communities and Technical Outreach to Brownfields Communities programs. Participants exchanged information about ways to provide assistance to communities affected by groundwater contamination, and hazardous substance cleanup, and site redevelopment. Co-sponsored by EPA and CWESt.

Co-sponsor, ***Northwest Stream Restoration Design Symposium***, Skamania, WA, February 2002. This conference created a forum for regulators, engineering and biology consultants, and educators to exchange information about technical issues in the design of stream restoration projects. An enthusiastic group of 250 people attended, a second annual event is planned for next year. The symposium was co-sponsored by CWESt, Portland State University, and Portland's Bureau of Environmental Services.

Seminar Series:

Spring 2001
Hydrology spring quarter series. The seminar brings nationally recognized hydrologists who focus on technical issues about water research. Oregon State University, Corvallis, OR, Co-sponsored by CWESt. Approximately 55 people attended each seminar in the series. Sponsored by CWESt.

Fall 2001
"Drought in the Northwest". Oregon State University, Corvallis, OR, Water Resources fall quarter series. Speakers discussed the drought from their perspective as the Oregon Water Resources Department Director, a water lawyer, reservoir regulator, USGS Water Resources hydrologists, and an environmental journalist. Approximately 55 people attended each seminar in the series. Sponsored by CWESt.

Workshops

"Taking the Future Seriously", Oregon State University -- This campus effort brought 25 people together for monthly meetings over the school year. It was funded by a grant from the Kellogg Foundation. The group met with provocateurs to challenge our thinking about how to integrate the future into our thinking and planning. CWESt brought four people to campus over the course of the past year; each speaker made a public presentation and then worked more intensely with the group in a separate session. A report will be published by the group which will include the lessons learned including mega-trends that OSU might consider in their planning process, techniques and strategies for thinking about the future, and a vision for the University's future.

Internships and Student Projects

Training Cooperative Partnership with US EPA – Under this cooperative agreement funded by the EPA, we have placed 20 undergraduates in research projects at the EPA Western Ecology Division offices over the past two years.
Undergraduate Research Team – CWESt sponsors an annual undergraduate research team who focuses on a sustainability topic each year. This year's team is focusing on green building design

and ways to integrate on-site stormwater management and other green technologies into the design of Oregon State's new engineering building.

Water Resources Education

Water resources minor students and students from across disciplines continue to be involved in CWESt to obtain information and grow academically. Students are attracted to the Center by its ongoing programs and the strong teaching and student advocacy skills of Water Resources faculty and staff. During the 2001 to 2002 year, CWESt:
Continued to sponsor, advise and promote the graduate minor in Water Resources; with disciplines in Water Quality, Hydrology, and Water Planning and Management.
Sponsored water resources seminars (see above).

Water Resources Education on the Web

CWESt staff developed several new program websites this year including:

- ◊ A new central site for CWESt – http://cwest.orst.edu
- ◊ New sites for the Groundwater Cleanup and Hazardous Substance Outreach Program including
    - o Technical Outreach Services for Communities and Technical Outreach Services for Brownfields Communities – http://tosc.orst.edu
    - o The Western Region Hazardous Substance Research Center – http://wrhsrc.orst.edu
    - o CWESt also maintained Oregon State's Water Resources Website which provides centralized information about water resources courses and faculty on campus (http://cwest.orst.edu/hydro/hydprog.html).

Regional Coordination and Cooperation

Program development activities include many contacts by the Center with water users and policy makers to stay abreast of statewide and local water problems. These contacts give direction to the centers program.

Cooperation with Universities in Oregon

CWESt advertises a range of research opportunities to research personnel at all universities and colleges with water programs in Oregon. This is done by phone and by emailing to known individual researchers, and by additional mailings to administrative offices. The Center is in contact with 14 universities and colleges in Oregon (Oregon State University, University of Oregon, Portland State University, Oregon Health Sciences University, Oregon Institute of Technology, Eastern Oregon State College, Southern Oregon State College, Western Oregon State College, Lewis and Clark College, Linfield College, Reed College, University of Portland, Willamette University, and the Oregon Graduate Institute).
Members of the CWESt advisory board have included representatives from Oregon State University, the University of Oregon, and Portland State University.

Statewide Coordination

Statewide coordination occurs through many of the Co-director's activities, including personal visits to state and federal agency offices, and service on various committees and task forces with members of local, state, and federal agencies. Telephone contacts offer another means of being aware of the activities of other groups and for coordinating Center activities with them. The Co-directors are aided in these efforts by members of the Center's Governing Board.
The Center receives and reviews newsletters, minutes of meetings, and annual reports from the Oregon Water Resources Department, Water Resources Commission, Department of Environmental Quality, Environmental Quality Commission, Department of Fish and Wildlife, Environmental Quality Commission, Department of Agriculture, Governor's Watershed Enhancement Board, Department of Energy, Bonneville Power Administration, Northwest Power Planning Council, and other state and federal agencies. These facilitate coordination of research activities to meet state needs and coordination of information dissemination to deal with problems and issues.

Regional Coordination

Program development activities in FY 2001 included regional research development discussions with the other water research centers in the Pacific Northwest. Directors of the state water research Centers of Alaska, Idaho, Montana, Oregon, Washington, Hawaii, and Guam work together on water-resource matters that involve teaching, research, and public service. The Columbia River system is a common concern for four of the above states.

CWESt also participates with the Water Resources Research Centers from Alaska, Idaho, and Washington in a regional Water Quality Research and Extension collaborative project funded by the US Department of Agriculture, Cooperative Research and Extension Program.

Research Support

In addition to administering the USGS minigrants (104B program), CWESt helped coordinate proposals which received the following grants during FY2001.

Grant Name or Program	Grant Dates	Total Grant Award
Cooperative Ecosystem Studies Unit (Lach, Herlihy, Hughes, Stevens, Woods, Ford)	06/02-05/05	$1,739,794
EPA Cooperative Training Program (Lach, Ford, Harding, Rosenberg, Herlihy, Li)	04/00-03/03	$927,216.18 ($309,072/yr)
US DOE, NABIR Program (Lach, Williamson, Semprini, Sanford)	07/01-06/03	$212,089 ($106,045/yr)
NSF, Biocomplexity in the Environment (Santelmann, Williamson, Lach, Moore, Huber)	09/01-08/02	$100,000
USEPA, Hazardous Substance Outreach (TOSC and TAB Programs) (Williamson, Lach, Harding)	09/01-08/02	$380,000
W.K. Kellogg Foundation	09/01-06/02	$10,000

The following unsuccessful proposal were facilitated by CWESt.

Williamson et al., proposal to National Science Foundation Digital Library Program for an online water resources education project

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	5	0	0	0	5
Masters	7	0	0	0	7
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	13	0	0	0	13

Notable Awards and Achievements

Shira Yoffe, OSU graduate student in Geosciences won the Universities Council on Water Resources Dissertation Context in the Water Policy and Socio-Economics category. Shira’s dissertation was titled, "Basins At Risk: Conflict and Cooperation Over International Freshwater Resources".

Publications from Prior Projects