Report No.
G1600-01

Fiscal Year 1988 Program Report
Grant No. 14-08-0001-G1600

for

U.S. Department of the Interior
Geological Survey

by

Wyoming Water Research Center
University of Wyoming
Laramie, WY 82071

Steven P. Gloss, Director

July 1989

The activities on which this report is based were financed in part by the Department of the Interior, U.S. Geological Survey, through the Wyoming Water Research Center.

ABSTRACT

Four research projects were funded under the FY88 program, as well as an information transfer program. Two projects funded through the WWRC state grants program were submitted as matching. A short statement identifying each project follows:

The mechanics of ground water recharge and the influences of geologic structure and stratigraphy on this recharge were studied for western Wyoming foreland and thrustbelt environments. Three distinct types of ground water storage were found to occur in these environments.

Uncertainty analysis and risk evaluation was performed on parameters of a dissolved oxygen (DO) water quality model. It was found that uncertainty in DO prediction depends on the classification of the stream and the use of a correct probability distribution for DO concentration.

Microorganisms which inhabit the rhizosphere are being studied to see if they play a major role in the modification of the bioavailability of selenium. Results to date suggest that vesicular arbuscular fungi found on the roots of plants in seleniferous soils are important mediators of plant selenium uptake.

An evaluation of potential toxicity effects of saline discharges from oil production operations on a portion of a stream system in Wyoming has indicated to date that concentrations of Na^+, K^+, Cl^-, HCO_3^- and CO_3^{2-} from these saline discharges is significantly contributing to observed toxicity.

The hydrologic, geomorphic and biologic responses of conveying municipal water through an ephemeral watercourse are being measured and evaluated. A well defined channel has begun to form and aquatic habitats are beginning to establish themselves.

The Wyoming Water Research Center operates and maintains a high mountain watershed observatory which is densely instrumented for the purposes of hydrologic, water quality, and climatologic research and educational instruction. It is presently being used by the U.S. Forest Service for atmospheric deposition studies in cooperation with the University of Wyoming.

Information transfer was accomplished through field tours, professional papers, a newsletter, law journal publications, seminars and updating data and bibliographic information sources for the State of Wyoming on regional and state water issues.

TABLE OF CONTENTS

WATER PROBLEMS AND ISSUES OF WYOMING

Wyoming's heritage stems from an abundance of natural resources. Vast areas of range and pastureland interspersed with fertile, irrigable stream valleys have enabled the agricultural and livestock industry to become a major driving force of the State's economy. The recreation and tourism industry thrives in Wyoming as visitors come to share the wealth of scenic beauty. Beneath the land surface lie such mineral resources as coal, oil and gas, uranium, oil shale, trona, gypsum, and iron ore. Their abundance has enabled Wyoming to become a national leader in mineral production.

Water is the key natural resource controlling the development of each of these facets of the State's economy. As the saying goes, "in Wyoming, water is life". The rancher could not survive our semi-arid climate without water for livestock and irrigation. Without our streams, lakes and reservoirs, the quality of the recreationists' experiences would be diminished. If the mineral industry is to continue to provide a major source of income in the State, water will be required. As our cities and towns continue to grow, adequate supplies of good quality water must be available.

Water availability and allocation for future agriculture, mineral extraction, industrial, recreation, and municipal purposes continue to be the center of water

related problems in Wyoming. The future management of Wyoming's water resources, in compliance with existing interstate water compacts and decrees, is a challenge in planning and implementation. Once available surface and groundwater supplies are utilized, their equitable distribution, conservation, and maintenance of quality become important legal and complex social issues.

The State of Wyoming is a water producing state to the Colorado River Basin, the Snake River Basin, and the Missouri River Basin. Approximately 15.5 million acre-feet of water are produced from snowfall and rain in Wyoming each year, with approximately 12 million acre-feet obligated for downstream use through compacts and decrees. Wyoming has embarked on a state supported water development program with the intended purpose of capturing for its use as much of the excess water produced as possible. The problems associated with the capture, diversion, dispersal, and re-use of these water resources are encompassing. In addition, being better able to forecast quantity and quality of water availability to downstream users is extremely important.

To address the problems and generate needed information associated with water conservation, development, and re-use, a truly interdisciplinary effort, well-managed and coordinated, is essential. The Wyoming Water Research Center is organized to provide that effort and can call upon a diverse set of disciplinary expertise necessary to address key issues for the State and the region.

PROGRAM GOALS AND PRIORITIES

Effective administration and management of Wyoming's water resources depend upon an understanding of the economic and social effects related to water development and utilization and the numerous physical relationships explicit in the hydrologic cycle. Through research there must be a means of assessing the social and economic impacts emanating from water development projects so that the State can utilize its water resources to achieve social and economic goals that fit within a legal and institutional framework that can control and finance water development actions and programs. This also requires equitable administration of Wyoming's water law using a working knowledge of many hydrologic processes. The hydrologic processes necessary to explain or account for the yield and quality of water from precipitation and snowmelt, and the movement and fate of pollutants of this water from saturated topsoil to aquifers, and aquifers to stream channels, is important. Improvement in the efficiency of water administration and management and the effect that water conservation measures for irrigation and other water uses such as energy and mining have on social, economic and hydrologic issues, must be assessed in Wyoming.

The Wyoming Water Research Center is part of both the Colorado and Missouri river basin regional organizations with other Water Resources Research Institutes. In compliance with the USGS guidelines, and in consultation

with state water officials and the Wyoming Water Research Center's Research Review and Priorities Committee, state and regional research priorities include, but are not restricted to, the following:

USGS PRIORITY RESEARCH AREAS (REGIONAL)

I. WATER QUANTITY

Water Distribution

Develop systems that are technically, economically, socially, and politically acceptable for the transfer of water from the areas of good supply to the areas of scarcity.

Dynamics of Ground Water/Surface Water Interaction

Develop and field test models explaining the ground and surface water interactions of different hydrologic areas of the region. This could include interactions involved in the processes of irrigation, flooding and recharge of ground water. It could include the importance and spatial variability of various parameters in the simulation models.

II. WATER QUALITY

Research in this area could include the fate and transport of agricultural chemicals as they move toward surface and ground water supplies. Such research might be on the adsorption mechanisms within the porous media, chemical reactions and degradation processes, flow characteristics of solutes and porous media, relative importance of the physical parameters in simulation models, methods for reducing the movement of contaminants, and application techniques.

III. INSTITUTIONAL RELATIONS

Research on the development of techniques to resolve conflicts among competing water was the most important in this category. This could include the refinement of institutional procedures of various water agencies as well as getting conflicting parties to accept and use each other's data.

IV. UTILIZATION AND CONSERVATION OF WATER

Enhancement of Water Use Efficiency

There could be research on more efficient systems for municipal, industrial and agricultural uses of water. This could include the development of techniques for producing the same amount of a product with less water, or more of the product with the same amount of or less water.

Improved Water Management

This could include the development of better management systems for municipal or irrigation use. Such systems might be those which better distribute the water or more efficiently manage it during peak demands. This could also include techniques for the reuse of water.

V. ECOLOGICAL/ENVIRONMENTAL RELATIONSHIPS

Instream Flow Needs

This research could include the instream flow needs for power generation, fish and wildlife management and recreational uses. It could be aimed at resolving the conflict between competing users of water.

Wetland Hydrology

Research here could establish the sensitivity to flow changes and multiple uses. It could establish the complementary relationships between farm ponds and natural wetlands. It could establish the importance of the wetlands as a hydrological resource.

Impact of Pollutants

Research in this topical area could include the chronic as well as acute effects of the various pollutants on the fish, wildlife and habitat vegetation.

WYOMING STATE RESEARCH PRIORITY AREAS

Specific research topic areas established by the WWRC Research Review and Priorities Committee include the following:

(Subject areas and subjects keyed with this symbol (*) were given a higher priority for funding consideration by the Research Review and Priorities Committee as long as the proposal had a satisfactory peer review.)

GROUND AND SURFACE WATER RESOURCES

a. Water Quantity and Management

- Recharge mechanisms
- Groundwater/surface water interactions (e.g., irrigation, flooding)
- Flow in the unsaturated zone
- Groundwater management

*b. Water Quality

*- Groundwater contaminant assessment, transport and cleanup
- Assessment methods for non-point sources
- Atmospheric deposition
- Septic systems

*c. Legal and Institutional Issues

- Interstate conflicts
- Interbasin transfers
- Use transfers
- Water leasing or marketing
- Federal reserve rights

WATERSHED AND RIPARIAN ZONE MANAGEMENT

a. Groundwater Storage

- Surface water hydrology effects
- Water rights
- Return flows
- Evapotranspiration

b. Surface Water Storage

- Headwater reservoirs
- Multiple reservoir management

c. Erosion and Sedimentation

- Novel control mechanisms
- Natural sediment loading
- Sediment/nutrient interactions

d. Non-Point Sources of Pollution

- Salinity
- Nutrients

e. Riparian Ecosystems

- Soils
- Vegetation
- Fish and wildlife
- Livestock

WATER DEVELOPMENT AND CONSERVATION

*a. Economic Assessment

*- Secondary benefits and costs (e.g., aesthetics, recreation, quality of life)
*- Tertiary (distant) benefits and costs
- Geothermal resources for agriculture
- Reservoir construction and management for efficient water utilization

*b. Legal and Institutional Issues

- Financing methods
- Use conflicts
- Conservation incentives
*- Public dissemination
- Water leasing or marketing

c. Environmental Relationships

- Instream flow
- Species of high state interest

d. Agricultural/Municipal/Industrial/Recreational Uses (Multiple Uses)

- Economic and social (public interest) development incentives and disincentives
- Long-term (10-20 yr) water needs (site/basin specific)

Emphasis on these priorities provided a logical stepwise framework for addressing water research needs as stated previously for the State of Wyoming and the region. To demonstrate the Center's implementation of priority research, Figures 1 and 2 indicate how our projects relate to the various topics under major research priority areas.

FIGURE 1

STATE OF WYOMING RESEARCH PRIORITIES AND PROJECTS

FUNDED BY USGS THROUGH THE WYOMING WATER RESEARCH CENTER

Fiscal Year 1988

	STATE OF WYOMING RESEARCH PRIORITIES											
	Ground & Surface Water Resources			Watershed & Riparian Zone Management					Water Development & Conservation			
RESEARCH PROJECTS FY88	Water Quantity & Management	Water Quality	Legal & Institutional	Groundwater Storage	Surface Water Storage	Erosion & Sedimentation	Non-Point Sources of Pollution	Riparian Ecosystems	Economic Assessment	Legal & Institutional	Environmental Relationships	Multiple Uses
Project #02 - Characterization of Mechanics, Rates, Water Qualities & Seasonal Variations Associated With Ground Water Recharge in the Upland Zones of Typical Wyoming Foreland & Thrust Belt Environments - P. Huntoon	X	X		X								
Project #03 - Uncertainty Analysis of Water Quality Models & its Applications to Risk Assessment & Mgmt. - Y.K. Tung	X	X										
Project #04 - Transformation & Plant Uptake of Selenium by Soil Microorganisms - S. Williams							X	X				

FIGURE 1

STATE OF WYOMING RESEARCH PRIORITIES AND PROJECTS

FUNDED BY USGS THROUGH THE WYOMING WATER RESEARCH CENTER

Fiscal Year 1988

STATE OF WYOMING RESEARCH PRIORITIES												
	Ground & Surface Water Resources			Watershed & Riparian Zone Management					Water Development & Conservation			
RESEARCH PROJECTS FY88	Water Quantity & Management	Water Quality	Legal & Institutional	Groundwater Storage	Surface Water Storage	Erosion & Sedimentation	Non-Point Sources of Pollution	Riparian Ecosystems	Economic Assessment	Legal & Institutional	Environmental Relationships	Multiple Uses
Project #05 - Assessment of Potential Environmental Impact of Saline Oil-Field Discharges into Salt Creek & the Powder River, WY - H. Bergman		X									X	
Project #06 - Evaluation of an Alternative Conveyance Strategy for Municipal Water - Q. Skinner & T. Wesche	X			X		X		X			X	X
Project #07 - Snowy Range Observatory: Maintenance & Evaluation - T. Wesche & Y.K. Tung	X	X					X					

FIGURE 2

FEDERAL RESEARCH PRIORITIES AND PROJECTS

FUNDED BY USGS THROUGH THE WYOMING WATER RESEARCH CENTER

Fiscal Year 1988

FEDERAL RESEARCH PRIORITIES									
	Water Quantity		Water Quality	Institutional Relations	Utilization and Conservation of Water		Ecological/Environmental Relationships		
RESEARCH PROJECTS FY88	Water Distribution	Dynamics of Ground/ Surface Water Interaction			Enhancement of Water Use Efficiency	Improved Water Management	Instream Flow Needs	Wetland Hydrology	Impact of Pollutants
Project #02 - Characterization of Mechanics, Rates, Water Qualities & Seasonal Variations Associated With Ground Water Recharge in the Upland Zones of Typical Wyoming Foreland & Thrust Belt Environments - P. Huntoon		X	X						
Project #03 - Uncertainty Analysis of Water Quality Models & its Applications to Risk Assessment & Mgmt. - Y.K. Tung			X						X
Project #04 - Transformation & Plant Uptake of Selenium by Soil Microoganisms - S. Williams								X	X

FIGURE 2

FEDERAL RESEARCH PRIORITIES AND PROJECTS

FUNDED BY USGS THROUGH THE WYOMING WATER RESEARCH CENTER

Fiscal Year 1988

FEDERAL RESEARCH PRIORITIES									
	Water Quantity		Water Quality	Institutional Relations	Utilization and Conservation of Water		Ecological/Environmental Relationships		
RESEARCH PROJECTS FY88	Water Distribution	Dynamics of Ground/ Surface Water Interaction			Enhancement of Water Use Efficiency	Improved Water Management	Instream Flow Needs	Wetland Hydrology	Impact of Pollutants
Project #05 - Assessment of Potential Environmental Impact of Saline Oil-Field Discharges into Salt Creek & the Powder River, WY - H. Bergman			X						X
Project #06 - Evaluation of an Alternative Conveyance Strategy for Municipal Water - Q. Skinner & T. Wesche		X					X	X	
Project #07 - Snowy Range Observatory: Maintenance & Evaluation - T. Wesche & Y.K. Tung		X	X						X

RESEARCH PROJECT SYNOPSES

SYNOPSIS

Project Number: 02 Start: 6/88 End: 5/89

Title: Characterization of Mechanics, Rates, Water Qualities, and Seasonal Variations Associated With Ground Water Recharge in the Upland Zones of Typical Wyoming Foreland and Thrust Belt Environments

Investigator: Huntoon, Peter W.
University of Wyoming, Laramie

COWRR: 04B **Congressional District:** First

Key Words: ground water recharge, aquifer characteristics, karst hydrology, groundwater quality

Problem and research objectives:

This project was designed to redress the lack of hydrogeologic information on ground water recharge in the upland recharge areas in western Wyoming foreland and thrust belt environments. The primary focus of the research is to document the influences of geologic structure and aquifer stratigraphy on ground water recharge processes, recharge rates, water qualities in the recharge areas, and seasonal variations in recharge and discharge rates. Specific attention is devoted to the influences of tectonic structure, aquifer and confining layer lithology, and geomorphologic setting on recharge characteristics in the alpine setting.

Municipalities and federal agencies responsible for ground water development in the study areas will benefit from this study because it will delineate upland recharge areas, reveal favorable exploration strategies, provide baseline water quality data, and quantify aquifer yield characteristics. Regional baseline data on ground water qualities in Wyoming's upland recharge areas is virtually nil.

The main objective of this project was to document the mechanics of ground water recharge in two different but widespread Wyoming environments: (1) foreland uplifts, and (2) thrust belt ranges. Particular attention was focused on recharge to the Paleozoic rocks in these uplands because it is these rocks which comprise the major aquifers in Wyoming's basins. The project investigated the influences of tectonic structures, aquifer and confining layer lithology, and geomorphic setting as they affect recharge rates, seasonal recharge variations, and water quality.

Methodology:

The Paleozoic rocks in the eastern Gros Ventre Range, a Laramide foreland uplift in northwestern Wyoming and the Salt River Range, a thrust belt setting also in northwestern Wyoming, were used as the main study areas.

The project was developed with a major field data collection effort followed by a data analysis phase in the two study areas. The field data collection involved:

1. Geologic mapping of lithologies and structures to delineate the geometry of the aquifers and identify tectonic structures that localize ground water movement utilizing color aerial photography and field verification.

2. Hydrostratigraphic definition detailing degree of hydraulic connection and permeability from field examination and drill hole data.

3. Spring discharge measurements for identification of seasonal trends in discharge and potentiometric mapping to define recharge areas and regional movement of ground water.

4. Water quality sampling of springs to characterize water qualities in the Paleozoic rocks.

5. Fracture fabric data of well exposed outcrops in the study areas to help identify recharge zones.

The data analysis was used to:

1. Define ground water basins and potentiometric maps in the area along with recharge-discharge characteristics of the basins.

2. Description of aquifer mechanics, permeability, storage and correlation with geologic structures.

3. Water quality relationships within the basin associated with major aquifers.

4. Identification and availability of ground water based on seasonal variation and geologic setting for exploration potential and yield.

Principal findings and significance:

Several structural features were identified for both areas in terms of faults and thrusts that were utilized in the analysis of recharge-discharge characteristics. In the

underformed backlimb of the eastern Gros Ventre Range, the Paleozoic rock comprises the Death Canyon, Madison and Tensleep aquifers. The small intergranular, intercrystalline, and fracture permeabilities in these aquifers have little influence on ground water circulation in the range. Large fracture and karst permeabilities associated with fault zones and epikarst permeabilities near the surface of carbonate beds have a much larger influence on ground water circulation in the eastern Gros Ventre and Salt River ranges than the smaller permeabilities of the underformed aquifers.

Three types of ground water storage were found to occur in the eastern Gros Ventre and Salt River ranges: (1) storage in a regional aquifer, (2) water in transit in deep but unsaturated karst systems, and (3) transient storage in epikarst zones perched above regional aquifers. Epikarst, which develops in outcrops of the Madison Limestone and Bighorn Dolomite on the backlimb of both ranges, transmits the major snowmelt in the area to ephemeral springs during the summer. Ground water discharged from the Tensleep aquifer supplies the major fall and winter streamflows in the study areas. Water quality samples collected indicated that the springs in the area were generally of good quality.

Publications and professional presentations:

None

M.S. theses:

Mills, John P. 1989. Foreland Structure and Karstic Ground Water Circulation in the Eastern Gros Ventre Range, Wyoming. M.S. thesis, University of Wyoming, Laramie, Wyoming. 101 p.

Ph.D. dissertations:

None

SYNOPSIS

Project Number: 03 Start: 6/88 End: 5/90

Title: Uncertainty Analysis of Water Quality Models and Its Applications to Risk Assessment and Management

Investigators: Tung, Yeou-Koung and Shih, Shagi-Di
University of Wyoming, Laramie

COWRR: 05G **Congressional District:** First

Key Words: optimization, systems analysis, water quality modeling, statistics, water quality management, Streeter-Phelps Equation

Problem and research objectives:

Water quality models are frequently used to assist water resource engineers and planners assessing the impact of various proposed water quality management plans. Most water quality models used in planning processes are deterministic without considering the existence of uncertainties in water quality models. Information obtained from such deterministic models is limited in the sense that single-value system response is obtained from the model. In reality, because of the existence of various uncertainties in water quality modeling, the system response under a given input condition is random which can only be assessed by probabilistic approaches. The result of probabilistic analysis provides a full spectrum of all possible system responses that can be utilized to make sound decisions in environmental management.

The research objectives include the following:

1. Perform uncertainty analysis on parameters of a water quality model for instream dissolved oxygen (DO) concentration prediction.

2. Assess the probability distribution of instream DO concentration for various classes of stream systems.

3. Develop a procedure for evaluating the risk of violating water quality standards.

Methodology:

In addition to the water quality parameters in the traditional Streeter-Phelps equation, the DO-BOD model considered

in this study included other oxygen sources and sinks that contribute to instream BOD and DO variations. The factors considered are: (1) removal of BOD by sedimentation or absorption; (2) addition of BOD along a stretch of stream due to scouring of channel bottom deposits; (3) addition of BOD along the stretch of stream by local runoff; (4) addition of oxygen by photosynthetic action; (5) removal of oxygen by the respiration of plankton and attached plants.

To investigate the relative importance of water quality with uncertainty, streams are categorized into four classes: sluggish, low, medium, and high velocity, according to Chadderton et al. (1982).

Uncertainty analysis was done by the Mean-Value, First-Order, Second-Moment (MFOSM) method. The result of such uncertainty analysis provides information about the relative contribution of water quality parameters to the overall uncertainty in DO prediction. Correlations among water quality parameters are also considered in the investigation.

In assessing the probability distribution of DO concentration, the Monte-Carlo simulation was employed. Various parametric probability distributions were used for the different stochastic water quality parameters, and their effects on the distribution of DO concentration were examined. The goodness-of-fit procedure was used to identify the most appropriate distribution for the DO concentration.

Advanced FOSM was used to evaluate the probability of violating water quality standards. The method is capable of taking into account non-normality of and correlation among stochastic water quality parameters. It overcomes the disadvantages of the MFOSM method, especially when the water quality model is highly nonlinear, which is the case for DO models. Comparisons were made regarding the accuracy of the two FOSM methods.

Principal findings and significance:

In uncertainty analysis, it was found that the relative importance of stochastic water quality parameters, in terms of their contribution to the total uncertainty in DO prediction, depends on the classification of the stream. This observation has implications for any water quality sampling program design for which the purpose is to reduce the uncertainty in DO prediction.

With regard to the distribution of DO concentration for either an assumed normal or lognormal distribution, it was found that in a great majority of the cases these two distributions provided the best fit. However, the most appropriate distribution (normal or lognormal) depends on

stream classification and types of oxygen source and sink terms in the water quality model. The use of the correct probability distribution for DO concentration has an important effect on the accuracy of computing the probability of violating water quality standards.

Compared with the results from a Monte-Carlo simulation, the Advanced FOSM method provides more accurate calculation for the probability of violating water quality standards than the Mean-Value FOSM method. However, computations involved in the Advanced FOSM method are more complex than those in the Mean-Value FOSM method. Judging from the environmental, ecological, social, and economic implications of such violation events, the ability to accurately assess violation probability with the Advanced FOSM method should override its disadvantage due to computational complexity.

Publications and professional presentations:

Tung, Y.K. 1989. Evaluating the probability of violating dissolved oxygen standard. Journal of Ecological Modelling. (in press)

Hathhorn, W.E. and Tung, Y.K. 1989. Water quality assessment in stochastic stream environments. Proceedings of 1989 ASCE National Conference on Environmental Engineering, July 10-12, Austin, Texas.

Tung, Y.K. Uncertainty analysis of DO models. Journal of Environmental Engineering, ASCE. (in preparation)

M.S. theses:

None

Ph.D. dissertations:

None

SYNOPSIS

Project Number: 04 Start: 6/88 (actual)
End: 12/90 (expected)

Title: Transformation and Plant Uptake of Selenium by Soil Microoganisms

Investigator: Williams, Stephen E.
University of Wyoming, Laramie

COWRR: 05B **Congressional District:** First

Key Words: biological treatment, plant growth, soil chemistry, soil microbiology, toxic substances

Problem and research objectives:

Roots draw many nutrients as well as water from the volume of soil or weathered parent material of the plant root zone. Additionally, the roots release carbon compounds into this zone which determine, to a degree, the types of microorganisms which will develop and inhabit this zone. In a somewhat larger sense, the rhizosphere can be viewed as a zone where compounds are transformed from the realm of the abiotic to that of the biotic by biological pathways. Selenium (Se) is one of these compounds of concern to cattle, sheep and other animals if plants make it available in a toxic form due to biological activity.

The major concern of this research is that microorganisms which inhabit the rhizosphere will have a major role in modification of the bioavailability of Se, but will also impact the rate at which plants take up Se. These are not unusual expectations of soil microorganisms. It is well known, for example, that bacteria can derive energy from the transformation of elemental sulfur or even sulfide to sulfate. Likewise, bacteria are involved in the transformation of nitrogen from atmospheric molecular nitrogen into bioavailable forms (nitrate and ammonium). It is also well documented that fungi which form symbioses with plant roots of most land plants are quite active in enhancing plant uptake of nutrients, water and non-nutrients. These fungi, known as mycorrhizal fungi, are among the most common of fungi and are essential for normal growth and development of many plants.

The objectives of this research are (1) enumeration and identification of bacteria and fungi in the rhizosphere which are capable of oxidizing selenides, and elemental selenium to selenates and selenites; (2) evaluate the potential for mycorrhizal and non-mycorrhizal test plants to

take up selenides, elemental selenium, selenites, and selenates; and (3) ascertain, in a controlled environment, the rate at which selenium can move from geologic parent material into test plants.

Methodology:

Two paired field sites are to be utilized. One in Albany County which is a seleniferous range site with an adjacent non-seleniferous range site. The other site will be in Natrona County with a seleniferous irrigated site and an adjacent non-seleniferous range site.

Extensive sampling at these sites will be conducted to determine the presence of selenium in soils, subsoils and parent materials. Soil samples will be taken with a soil auger to the depth of the plant root zone. Samples will be examined for total selenium and DTDA-TEA extractable selenium. A test pit will be excavated at each site to classify soils and for subsampling of each soil horizon for chemical, physical and biological properties. Biological properties will include determination of selenium oxidizing organisms and examination of roots for symbionic fungi. Selenium oxidizing organisms will be determined by plating dilutions of target soils on solid media containing different levels of selenium. Above ground plant parts will be analyzed for total selenium.

A factorial study design will be used to examine four forms of selenium that may be stored in plant tissue as a result of mycorrhizal fungi activity involved in plant uptake of selenium. Each treatment with mycorrhizal fungi will be replicated five times. Mycorrhizal and non-mycorrhizal plants will be grown on soil supplements with selenium species. Uptake will be determined via plant analysis.

Principal findings and significance:

The accomplishments and findings on this project to date have been:

1. The identification of the two paired field sites and sampling at the field sites in Albany County.

2. Selenium reducing bacteria are very common in most of the seleniferous soils that have been examined to date. Selenium oxidizing organisms are present, but seem less abundant.

3. At the field sites in Albany County, soil samples have been collected along with plant roots, tops and nodules.

4. Selenium content of the soils were in the range of 1 ppm maximum. Plants demonstrated a higher selenium content than the soil suggesting that accumulation occurs. The concentration of selenium in root nodules was a factor of 10 to 50 times greater than in other parts of the plant.

5. Roots that were collected for staining purposes to detect the presence of vesicular arbuscular mycorrhizae were found to have an abundance of these fungi. A laboratory study has suggested that vesicular arbuscular fungi are important mediators of plant selenium uptake.

Publications and professional presentations:

Williams, Stephen E. Influence of rhizosphere microorganisms on uptake of selenium by two-grooved and tine leaved milkvetches. To be presented at the American Society of Agronomy Annual Meeting (Soil Microbiology and Biochemistry Division) in Las Vegas, Nevada, October 15-17, 1989.

M.S. theses:

None

Ph.D. dissertations:

None

SYNOPSIS

Project Number: 05 Start: 6/88 (actual)
End: 5/90 (expected)

Title: Assessment of Potential Environmental Impact of Saline Oil-Field Discharges into Salt Creek and the Powder River, Wyoming

Investigator: Bergman, Harold L.
University of Wyoming, Laramie

COWRR: 05C **Congressional District:** First

Key Words: toxic substances, brackish water, water quality control, industrial waste water

Problem and research objectives:

Discharge of oil field effluents is becoming a controversial issue in key oil producing regions of Wyoming and other western oil states. Concerns are based on potential effects of toxic and saline releases from oil production to ground and surface waters. The waters produced are typically high in total dissolved solids and have ionic compositions qualitatively similar to seawater. In addition, they may also contain a variety of other inorganic and organic constituents, all of which have a potential for toxicity to freshwater organisms. But, relatively little is known of the toxicity and persistence of these discharges in receiving waters.

Such environmental and regulatory concerns are prominent in the Salt Creek drainage of the Powder River Basin in Wyoming. Salt Creek, a major tributary of the Powder River in northeastern Wyoming, flows through a large oil-producing basin. The natural flow of Salt Creek is very low but is increased up to 49 million gallons per day by large inputs of saline discharges from oil production operations. Adverse impacts from these discharges can affect wildlife, agriculture and municipalities that use water from Salt Creek and the Powder River.

To evaluate potential effects of saline discharges on Salt Creek and the Powder River, we adopted two relatively quick, sublethal toxicity tests using fish and invertebrates. Our objectives in this study were to (1) estimate the ambient toxicity of Salt Creek waters and the persistence of this toxicity downstream, (2) characterize the salt load and organic compounds introduced by oil-field effluents, (3) determine the contribution of salts, organic compounds and other materials to the toxicity of Salt Creek and Powder

River waters, and (4) conduct a qualitative survey of stream fauna to identify any noticeable changes as discharges enter the drainages.

Methodology:

Water samples from three sites in Salt Creek and three sites in the Powder River were collected three times in 1988, during high, medium and low flow periods for the rivers. Each water sample was tested for its effects on survival and growth of fathead minnows (Pimephales promelas) and survival and reproduction of Ceriodaphnia dubia, an aquatic invertebrate. Chemical analyses of the water samples included routine water chemistry parameters, major inorganic ions, ten trace elements, and reverse-phase HPLC gradients. Macroinvertebrates and vertebrates were qualitatively sampled at each site and preserved for identification.

Principal findings and significance:

There were no significant effects on fathead minnow survival, compared to the upstream Salt Creek control, in any of the test waters. Fathead minnow weights were significantly ($P < 0.05$) reduced at the upstream Powder River site during high flow and at all sites during low flow, compared to the upstream Salt Creek control.

Ceriodaphnia were more severely affected. None survived in Salt Creek waters below the oil fields during any of the sampling periods. During low flow, no Ceriodaphnia survived in Powder River waters below the confluence with Salt Creek. Where Ceriodaphnia survival was good, reproduction was too. There were no significant ($P < 0.05$) reductions in the mean number of young produced, compared to the upstream control, with the exception of the Irigary bridge site during medium flow. Diluting the toxic waters by 50 percent with reconstituted water reduced the toxicity in most cases.

No organic compounds were found in any of the sample waters analyzed by HPLC methods. Trace element concentrations in downstream waters did not differ considerably from the upstream Salt Creek water.

Concentrations of Na^+, K^+, Cl^-, HCO_3^- and CO_3^{2-} increased considerably in Salt Creek waters collected downstream of the oil field discharges, and pH values increased also. Regression analyses indicated that these parameters significantly contributed to the observed toxicity.

The qualitative macroinvertebrate and vertebrate survey did not reveal any obvious trends that could be correlated with saline discharges from oil fields.

Publications and professional presentations:

Lamming, F.N., A.M. Boelter, D.R. Mount, J.D. Fernandez and H.L. Bergman. 1988. Effects of saline-oil field discharges into surface waters. Presented at the Ninth Annual Meeting of the Society of Environmental Toxicology and Chemistry. Arlington, Va. November 13-17.

M.S. theses:

None

Ph.D. dissertations:

None

SYNOPSIS

Project Number: 06 Start: 6/88
End: 5/89

Title: Evaluation of an Alternative Conveyance Strategy for Municipal Water

Investigators: Skinner, Quentin D. and Wesche, Thomas A. University of Wyoming, Laramie

COWRR: 03D **Congressional District:** First

Key Words: conveyance systems, fisheries, geomorphology, plant-water relationships, streams

Problem and research objectives:

An alternative method for conveyance which to date has received little, if any, attention is the controlled release of diverted water into ephemeral watercourses, thereby creating a perennial stream with a flow regime similar to a spring-fed system. The City of Cheyenne, Wyoming is presently being required by the U.S. Forest Service, under advisement with the U.S. Fish and Wildlife Service and the Wyoming Game and Fish Department, to pursue such a conveyance strategy as one mitigation measure for its Stage II water development program. The intent is that, through this unique delivery system, municipal water can be used for aquatic and riparian resource enhancement. Little is known regarding the potential for success of this mitigative action.

The nature and scope of this study has been, and will continue to be, to measure and evaluate the hydrologic, geomorphic and biologic response of conveying municipal water through an ephemeral watercourse, thereby: 1) promoting channel development by means of an introduced, stable water supply, and (2) possibly enhancing aquatic and riparian resources for alternative multiple uses. Specific objectives expected to be met through performance of the proposed research include:

1. To measure and evaluate the geomorphic and hydrologic processes involved in the development of perennial stream channels from previously ephemeral watercourses.

2. To measure and evaluate the response of the riparian resource to flow regime augmentation.

3. To measure and evaluate the response of the aquatic resource to flow regime augmentation.

4. To analyze the overall aquatic and riparian habitat trade-offs resulting from diversion of water from a perennial to an ephemeral stream, thereby providing guidelines for management agencies to assess conveyance strategies for future water development programs.

Methodology:

The stream system that is being investigated is the South Fork of Middle Crow Creek (SFMCC) and one of its tributaries. The SFMCC is located within the Pole Mountain Research Watershed in the southeastern corner of Wyoming about halfway between the cities of Laramie and Cheyenne. The headwaters of this previously-ephemeral stream originate approximately 8,200 feet above mean sea level, and continue in an easterly direction for approximately 10 miles to its confluence with the Middle Fork of Crow Creek before reaching Crystal Lake Reservoir. Five and one half of these miles are included within the Medicine Bow National Forest. The lower limit of the study watershed ends at the forest boundary and includes approximately 3.2 square miles of contributing area. In addition to the flow-augmented watershed, several nearby control watersheds have been established to compare the effects of flow augmentation with natural ephemeral streams. Historically, the SFMCC within the proposed study area was an ephemeral stream which flowed primarily in response to spring snowmelt and intense precipitation events.

To assess the rate of channel development in response to flow augmentation, 57 cross sections were permanently marked and surveyed across the valley floor. Cross sections were located based upon the channel gradient, vegetation type, and the type of control exhibited. In addition, 15 transects were established on control watersheds to compare the rate of natural ephemeral channel development with augmented flow channel development. Each of the 72 permanent cross sections are resurveyed during the spring and fall of each year to quantify response to augmentation.

Associated with each valley-floor cross-section are four shallow alluvial groundwater wells, cased with two-inch PVC, to evaluate the change in shallow groundwater storage. This provides a network of 234 wells on the treated watershed and an additional 60 wells on the control watersheds.

In coordination with the groundwater well network, six Parshall flumes were installed and equipped with water stage recorders to measure the change in surface flows along the South Fork of Middle Crow Creek over time. With the surface water network and periodic measurements of all tributary inflow, estimates of channel conveyance losses of released water will be made through the system.

To assess precipitation-runoff relationships, two Belfort recording precipitation gages equipped with Alter Shields were installed near the upper and lower ends of the study area.

Dominant plant communities were delineated using 1:24000 aerial photographs enlarged to a scale where approximately 10 inches equals 1 mile. These preliminary plant community boundaries were ground truthed by visual reconnaissance and line transect techniques. Pre-augmented streamflow plant community boundaries were finalized using these field data transferred to a baseline plant community map.

Pre-augmented streamflow study sites were selected with the aid of this plant community map and visual site inspection. Each site was located near an existing groundwater-well transect along a permanently marked valley bottom-cross section, so the water table and surface profile data could be used to help explain a plant species response to streamflow augmentation. To separate the livestock grazing effects from the influence of streamflow augmentation on the riparian plant communities, study sites were also located both inside and outside livestock grazing exclosures for each dominant riparian plant community type where possible.

A total of 6 tree, 4 shrub, 33 herbaceous vegetation, and 4 beaver sites are being sampled each year within the study area. These will be utilized to detect shrub, plant and tree community changes as a result of flow augmentation.

Livestock suitability and usability maps have been developed for the SFMCC riparian zone study area from the pre-augmented streamflow plant community map. After the completion of this study, a revised plant community map showing the areal extent of plant community change will be compiled from the information gained in this study. New livestock suitability and usability maps will then be determined from the revised plant community map.

Principal findings and significance:

During the summer and fall of 1988, the fourth field season on the South Fork of Middle Crow Creek (SFMCC) and related watersheds was completed. Work continued on schedule for each of the five major research areas: channel morphology, surface hydrology, groundwater hydrology, riparian vegetation and aquatic habitat. An M.S. thesis has been completed on herbaceous riparian vegetation, and research is continuing on the SFMCC as a topic for a Ph.D. dissertation. Following is a summary of the work completed and the present status of each area.

Channel Morphology

All 57 valley cross sections on the SFMCC, plus the 15 valley cross sections on the comparison watersheds, were resurveyed in October. Headcut migration was remeasured for all headcuts downstream of Exclosure #4, but the SFMCC froze before the remaining headcuts could be measured. This work will be completed in the early Spring, prior to snowmelt runoff, if possible. Preliminary testing of a method to evaluate channel initiation was conducted in November.

Surface Hydrology

Both the upper and lower precipitation gages continued to be operated on a year-round basis and were changed from weekly to monthly charts in late November. All six stream gaging stations were equipped with recorders this year and were checked on a weekly basis through late November. Beginning in late November, the main outlet gate and Garvin's gage were equipped with heaters and will be checked monthly throughout the winter. The other gages were shut down for the winter. Suspended sediment and bedload samples were collected at each gaging station on a weekly basis through early summer. Flow augmentation was again intermittent throughout the summer, with periods of no augmentation lasting up to eight weeks in duration. A time-of-travel study using Rhodamine-WT was again conducted last summer for the entire SFMCC study reach. All data will be reduced and loaded into the Water Resources Data System (WRDS) this winter.

Groundwater Hydrology

Approximately 300 shallow groundwater wells have been installed on the SFMCC watershed since the project began. These wells were measured on a monthly basis from May through October. Beginning in November, a representative sample of wells will be monitored on a monthly basis throughout the winter. Groundwater will be reduced and loaded into the database this winter.

Riparian Vegetation

Shrub and meadow sites were sampled for the third time last summer. The UW Range Management Department clipping crew again provided assistance with the field sampling in the meadows. A manuscript concerning the response of the herbaceous-riparian vegetation to two years of streamflow augmentation is in preparation and will be submitted to Regulated Rivers: Research and Management early in 1989.

Aquatic Habitat

A manuscript has been accepted by Regulated Rivers: Research Management and should be published in mid-1989. During the latter half of 1988, aquatic habitat monitoring consisted of observations of brook trout in the beaver ponds. One brook trout was observed downstream of a beaver pond in the poorly channelized meadows about six weeks after flow augmentation returned to the meadows. Detailed habitat sampling is again scheduled for 1989.

Publications and professional presentations:

Henszey, R.J. 1988. Riparian zone changes caused by streamflow augmentation. Water Talk: An Interdisciplinary Seminar Series. November 9, 1988, University of Wyoming, Laramie. Sponsored by the Wyoming Water Research Center.

Henszey, R.J., S.W. Wolff, T.A. Wesche and Q.D. Skinner. 1988. Assessment of a flow enhancement project as a riparian and fishery habitat mitigation effort. In: Restoration, Creation, and Management of Wetland and Riparian Ecosystems in the American West. A symposium sponsored by the Rocky Mountain Chapter of the Society of Wetland Scientists, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S. Bureau of Land Management. November 14-16, 1988, Denver, CO. (in press).

Wolff, S.W. 1988. Radio interview on "Insight", University of Wyoming state-wide broadcast, December.

Wolff, S.W. , T.A. Wesche and W.A. Hubert. 1989. Stream channel and habitat changes due to flow augmentation. Regulated Rivers: Research and Management. (in press)

Henszey, R.J., Q.D. Skinner and T.A. Wesche. Sedge, tufted hairgrass and reedgrass response after two years of streamflow augmentation. Regulated Rivers: Research and Management. (in preparation)

Now that a channel is beginning to form, we anticipate additional use of the SFMCC as both a research demonstration and a teaching watershed. Presentations have been made to several Range Management watershed classes in the past, and another is planned for this Spring. We also hope to organize a tour early this coming summer for state and federal agency personnel who have been involved with the study.

M.S. theses:

Henszey, R.J. 1988. Sedge, hairgrass, and reedgrass response after two years of streamflow augmentation. M.S. thesis, Department of Range Management, University of Wyoming.

Wolff, S.W. 1987. Evaluation of trout habitat formation due to flow enhancement in a previously ephemeral stream. M.S. Thesis, Department of Zoology, University of Wyoming.

Ph.D. dissertations:

None

SYNOPSIS

Project Number: 07 Start: 6/88
End: 5/89

Title: Snowy Range Observatory: Maintenance and Evaluation

Investigators: Wesche, Thomas A. and Tung, Yeou-Koung
University of Wyoming, Laramie

COWRR: 02B **Congressional District:** First

Key Words: mountain lakes/streams, sedimentation, watershed management, weather data collection, statistics

Problem and research objectives:

The Snowy Range Observatory (SRO) is a densely instrumented hydrologic and climatologic research and educational watershed located in the Snowy Range Mountains 35 miles west of Laramie, Wyoming. Centered in the 7.5 sq. mile Nash Fork Creek drainage of the Medicine Bow National Forest, the SRO has been maintained by WWRC and its predecessor WRRI since the late 1960s. The basic data collection network consists of 21 recording precipitation gages, 8 recording hygrothermographs, 6 anemometers (2 recording and 4 totalizing) and 7 streamflow gaging stations. Instrumentation extends along an elevational gradient from the Centennial Ranger Station at 8,440 feet above mean sea level up to over 11,000 feet at Lost Lake. Data collection is on a weekly basis throughout the year, with all data entered onto the Water Resources Data System (WRDS).

Recently a survey has been completed by WWRC of currently operational research watersheds in the Rocky Mountain region. Results indicate that 95 such facilities exist in the states of Montana, Idaho, Utah, Colorado, New Mexico, Arizona and Wyoming. Survey results further indicate that, based upon period-of-record, intensity and diversity of instrumentation, seasons of use, ecological diversity, and data analysis capabilities, the SRO is a truly unique and valuable research and educational resource.

The benefit derived from continued operation of the Snowy Range Observatory is the maintenance of a long-term continuous record of streamflow and climatic data collected for use with present and future research studies within an alpine watershed.

This project presently has two ongoing major efforts: (1) the continued operation and maintenance of the SRO instrumentation network and (2) a statistical analysis of the

present design of the existing network to determine if a reduction in data collection sites can occur along with greater automation.

Methodology:

Maintenance of the SRO is done on a weekly basis. This work entails primarily the changing of charts on the recording instruments, a check of the proper functioning of each instrument, and the conduct of any needed repairs. Each instrument is recalibrated on an annual basis. During the spring and summer, rating curves for each stream gage station are updated through the continual measurement of discharges, and sediment transport samples are also collected. Also, any major repair work (e.g., rebuilding of Wyoming shields) is done at this time. Charts are reduced by a part-time student data clerk into tabular form for entry on the WRDS database system. Computer entry is performed by the WRDS staff.

A Graduate Research Assistant (GRA) assigned to the project during the next two years will assist with the evaluation of the present network design. Working closely with the co-principal investigators, the GRA will become familiar with the uniqueness of the SRO and be trained in statistical analysis of hydrologic data. To lay the groundwork for further analyzing the adequacy of the existing hydrologic network, it is proposed that analyses be performed during the budget period to identify the basic statistical characteristics of hydrologic information in the SRO. This evaluation will include temporal and spatial correlation structures of each individual hydrologic variable and cross-correlation among various hydrologic variables. The GRA's thesis topic will be generated from this analysis.

Principal findings and significance:

Since its establishment, the SRO has served as the study area for a variety of hydrologic, climatologic and biologic research projects involving many departments and units at the University of Wyoming. The results of this work have been detailed in 35 water resource series publications, 23 Master's theses and Ph.D. dissertations, and 58 journal articles and proceedings papers. Also, the SRO has been used to educate over 100 graduate and undergraduate students in watershed data collection and analysis techniques. It is presently within the study area of the Glacier Lakes Ecosystem Experimental Study Site of the U.S. Forest Service and University of Wyoming in cooperative research efforts on background studies of a pristine area to atmospheric deposition and transport.

Each year the data collected on the SRO have been reduced to a tabular form and entered on the WRDS database system for researchers and others to use who are interested in alpine watershed characteristics. The data are kept current.

Additional slides were taken of the Snowy Range Observatory and data collection procedures within the Observatory to enhance a slide series developed for both on- and off-campus groups.

The draft report regarding the significance of the Snowy Range Observatory in comparison to other Rocky Mountain research and demonstration watersheds has been completed and is in final review.

Regarding statistical evaluation of the network, monthly streamflow data from seven streamflow gages have been analyzed. The autocorrelation and cross-correlation of the seven stations were calculated. Currently, the analysis of statistical characteristics for the 20 precipitation gages is under way. The primary difficulty encountered thus far in the streamflow analysis has been the presence of missing data. This appears to be the case for the precipitation data as well. In order to improve the completeness and reliability of the data, the investigation and development of methodologies for better estimating missing data in the records will be developed. It is believed that such procedures can be incorporated into the WRDS as part of the analysis software.

During July, the Observatory served as the site of a field tour for the Wyoming Water Institute for Teachers. Objectives of the two-hour session were to demonstrate how hydrologic data are collected from a high mountain watershed and why such data are important for land use management decision making and research.

Publications and professional presentations:

It is difficult to identify specific publications resulting from the Observatory. Therefore, such information is indicated as accurately as possible under principal findings and significance given above.

M.S. theses:

None

Ph.D. dissertations:

None

INFORMATION TRANSFER ACTIVITIES

June 1, 1988 - May 31, 1989

The Wyoming Water Research Center uses several networks to inform the people of Wyoming, as well as neighboring states and regions, of what the WWRC is doing in cooperation with state and federal agencies to protect Wyoming's water. University of Wyoming faculty, working through the Wyoming Water Research Center, have reported their research results in professional journals and at conferences. Research results are also disseminated through technology transfer efforts by organized workshops, seminars, etc.

FORMAL GATHERINGS AND PRESENTATIONS

Motorized bus tours highlight Wyoming's water resources and streamside zone concepts and provide an opportunity for participants to observe and discuss water related resource issues.

The following tours were co-sponsored by the Wyoming Water Research Center.

1. **The Governor's Economic Development Seminar and Field Tour of Carbon County was held August 24-26, 1988.** Participants were invited by the Governor to inventory, review and discuss the economic resources available in Carbon County and examine economic development potentials for Carbon County and the State of Wyoming. Ten communities in Carbon County were visited and the resources particular to that community were highlighted.

2. Governor Sullivan appointed a state work group to coordinate selenium research efforts in Wyoming. Selenium problems highlighted by Kesterson in California triggered concerns throughout the West, including Wyoming. The work group will monitor selenium information and keep the Wyoming public informed. The WWRC Associate Director for Information Dissemination was appointed to serve on the selenium work group.

A selenium information tour was planned and conducted on the Casper-Alcova Irrigation District June 2, 1988. An information brochure, which contained basic information about selenium, was prepared and distributed to tour participants and the public.

Organizational Meetings and Conferences

1. **Riparian Work Group**

Riparian zone policy in several western states prompted the establishment of a working group in Wyoming. In order to ensure that discussions about riparian zone policy result in sound management rather than division and controversy, several western states have organized riparian working groups. Governor Sullivan and the Wyoming Water Research Center invited interested parties to meet and discuss the formation of a riparian working group in Wyoming. Federal and state agencies, UW faculty and environmental groups have held organizational meetings in Cheyenne on February 1, 1989, and in Casper, April 10, 1989.

2. **Global Climate Change Conference**

A conference entitled, "Global Climate Change: Impacts and Opportunities for Wyoming and the Region" was presented by the Wyoming Water Research Center at the University of Wyoming, April 24-25, 1989. Speakers were invited who had national and international expertise on the subject of global warming and its effects on the environment.

Education and Instruction

1. **The Legislative Water Resources and Law Forum** was held January 5, 1989 in Cheyenne. The Forum was co-sponsored by the Legislative Services Office and was attended by approximately 1/3 of the Legislature. Topics of discussion included water terms, Wyoming's water supplies and uses, Wyoming water law, compacts and court decrees, Wyoming Water Development Commission, North Platte River Issues, endangered species and river management on the Platte and Colorado River Systems, proposed water legislation and economics of water development in Wyoming.

2. Faculty from the UW and WWRC conducted a series of **water resources workshops** for 900 ninth grade students at the Casper Junior High School. These workshops were held in seven classes per day during April 17-21, 1989.

3. Two public water resources seminars are held annually which are structured to permit open discussion between people interested in the management and development of Wyoming's water resources. The Water Resources Seminars for 1989 were held January 25-26 and January 31, in Powell

and Torrington, respectively. Water issues relating to the drought and availability and prediction of water supplies, water quality legislation and regulations were addressed. Between 30 and 50 people attended each seminar.

4. **Water Institute for Teachers.** A summer school course is offered annually for elementary and secondary science teachers with topics relative to water resources. In cooperation with the UW Center for Teaching and Learning, the workshop was held July 11-22, 1988 at the University of Wyoming. Participants receive two credit hours. Fifteen Wyoming teachers participated.

5. The **Water Talk Seminar Series** provides a forum for discussion of water resources related studies and activities conducted by UW faculty, staff and graduate students. Video tapes were produced of some of the talks and made available for use to the general public and state agencies for informal or regularly scheduled showings to personnel, or for use by field or regional offices. Students in the water resources graduate program are given one hour credit and are required to make a formal presentation of their thesis topic at the seminar. Faculty working on research funded by the WWRC are a regular part of the seminar series.

INFORMATION TRANSFER PUBLICATIONS

1. Volume 1, No. 1, February 1989 of the **Wyoming Hydrogram** began a tradition of newsletter reporting for the Wyoming Water Research Center. This bi-monthly newsletter is distributed to a mailing list of approximately 1300.

Features of each newsletter include a guest editorial, a note from the WWRC director, people profiles, activities of the WWRC faculty, staff and students, research briefs, and national, regional and state water resources news. The goal is to communicate to the readers the history, purpose and activities of the WWRC.

2. **"WWRC News"** In "Wyoming Water Flow Newsletter", published monthly by the Wyoming Water Development Association. Subscriptions total approximately 700.

3. The College of Law at the University of Wyoming produces a refereed law journal on a semi-annual basis entitled, **"Land and Water Law Review".** Publication costs are partially funded by the Wyoming Water Research Center. Several articles each year on western water issues are published in this journal. Titles and authors of water articles published this past year are listed below.

Aldo Leopold and Western Water Law: Thinking Perpendicular to the Prior Appropriation Doctrine, C.F. Wilkinson, Land and Water Law Review, Volume 24, No 1, 1989.

Wyoming's Groundwater Laws: Quantity and Quality Regulation, L.J. Wolfe and J.G. Hager, Land and Water Law Review, Volume 24, No. 1, 1989.

Comment - Indian Reserved Water Rights: An Argument for the Right to Export and Sell, C. Lichtenfels, Land and Water Law Review, Volume 24, No. 1, 1989.

A Critical Look at Wyoming Water Law, M. Squillace, Land and Water Law Review, Volume 24, No. 2, 1989.

Case Note - Water Law - The United States Supreme Court Expands the Public Trust Doctrine. Phillips Petroleum Co. v. Mississippi, D.J. Gardner, Land and Water Law Review, Volume 24, No 2, 1989.

4. The Center maintains a listing of water-related journal articles and publications resulting from research projects. Also included as Appendices are water-related articles published in the Land and Water Law Review, a description of the Wyoming Water Bibliography, and a compendium of graduate theses submitted by students participating in the UW interdisciplinary water research and academic programs.

5. A directory of water resources individuals from state and federal agencies in Wyoming, prepared in cooperation with the State Water Forum, is available from the Wyoming Water Research Center.

INSTITUTIONAL-SUPPORTED PROFESSIONAL PUBLICATIONS

Technical Completion Reports:

Foster, J.R., L.O. Pochop and R.D. Burman. 1988. A comparison of two methods for measuring phreatophyte transpiration: porometry and weighing lysimeter. Technical Completion Report to the Geological Survey (USGS G1459-02). 38 p.

Wiersma, U.M., V.R. Hasfurther and G.L. Kerr. 1988. Structural obstruction of recharge to the Paleozoic aquifer in the Denver-Julesburg Basin along the Laramie Range, Wyoming. Technical Completion Report to the Geological Survey (USGS G1459-04). 56 p. + maps.

Lockwood, J.A. and L.D. Debrey. 1988. Impact of sedimentation on the aquatic macroinvertebrates of the North Fork of the Little Snake River. Technical Completion Report to the Geological Survey (USGS G1459-05). 121 p.

Marston, R.A. and L.S. Dolan. 1988. Estimates of upland erosion and runoff in an arid watershed in Wyoming. Technical Completion Report to the Geological Survey (USGS G1459-06). 106 p.

Parker, M. and T.E. Fannin. 1988. Techniques for Augmenting Water Quality Data: Application to Flaming Gorge Reservoir and to Sampling Protocols. Report to the Wyoming Water Research Center. 199 p.

Wesche, T.A., Q.D. Skinner, V.R. Hasfurther and S.W. Wolff. 1988. Stream Channel Response to Flow Depletion. Report to the Wyoming Water Development Commission. 20 p.

Hasfurther, V. and E.L. Johnson. 1988. Feasibility Study for the Establishment of a Hydrologic Model Library at the Wyoming Water Research Center. Report to the Wyoming Water Development Commission. 114 p.

Journal Articles:

Hathhorn, W.E. and Y.K. Tung. 1988. Assessing the Risk of Violating Stream Water Quality Standards. Journal of Environmental Management 26:321-338.

Sullivan, P.J., J.L. Yelton and K.J. Reddy. 1988. Iron Sulfide Oxidation and the Chemistry of Acid Generation. Environ. Geol. Water Sci. 11(3):289-295.

Sullivan, P.J., J.L. Yelton and K.J. Reddy. 1988. Solubility Relationships of Aluminum and Iron Minerals Associated with Acid Mine Drainage. Environ. Geol. Water Sci. 11(3):283-287.

Tung, Y.K. 1988. Multi-Objective Detention Basin Design in Urban Drainage Systems - Tradeoff Between Risk and Cost. Water Resources Management 2:57-62.

Carter, G.A., W.K. Smith and J.L. Hadley. 1988. Stomatal conductance in three conifer species at different elevations during summer in Wyoming. Can. J. For. Res. 18:242-245.

Reddy, K.J., P.J. Sullivan and J.L. Yelton. 1988. Solubility Relationshps of Zinc Associated with Acid Mine Drainage. Journal of Environmental Quality 17(4):712-714.

Tung, Y.K. and W.E. Hathhorn. 1988. Assessment of Probability Distribution of Dissolved Oxygen Deficit. Journal of Environmental Engineering 114(6):1421-1435.

Symposia Proceedings

Dolan, L. and R.A. Marston. 1988. Factors Influencing Rainsplash Erosion and Runoff in an Arid Watershed. In Water and the West, Proceedings of a Symposium on Water Resources and Related Issues, April 28-29, 1988, ASCE, Wyoming Section, pp. 137-142.

Other

Hasfurther, V.R. (ed.). 1988. Directory of Water Resources Individuals from State and Federal Agencies in Wyoming.

Grafton, S., J.D. Rodgers, P. Schwieger and D.J. Brosz (eds.). 1988. Governor's Economic Development Seminar and Field Tour, Carbon County, Wyoming, August 24-26, 1988: Comments and Suggestions From Tour Participants, 30 p.

State Selenium Work Group. 1988. Selenium Information Tour--Kendrick/Casper-Alcova Irrigation District. 11 p. + map.

Price, R.E. (ed.). 1989. Governor's Economic Development Field Tour of Fremont County, Wyoming: Tour Guide and Information Booklet, June 28-30, 103 p.

Gloss, S.P. (ed.). 1989. Wyoming Hydrogram. Bimonthly newsletter published by the Wyoming Water Research Center with funds provided in part by the U.S. Geological Survey, Department of the Interior.

Land and Water Law Review, College of Law, University of Wyoming. Biannual publication to which the Wyoming Water Research Center contributes funds provided by the U.S. Geological Survey, Department of the Interior for publishing costs.

USGS Funded Publications Listing

Huntoon, P.W. 1989. Characterization of Mechanics, Rates, Water Qualities, and Seasonal Variations Associated with Ground Water Recharge in the Upland Zones of Typical Wyoming Foreland and Thrust Belt Environments.

Tung, Y.K. 1989. Uncertainty Analysis of Water Quality Models and its Applications to Risk Assessment and Management.

Williams, S. 1989. Transformation and Plant Uptake of Selenium by Soil Microoganisms.

Bergman, H. 1989. Assessment of Potential Environmental Impact of Saline Oil-Field Discharges into Salt Creek and the Powder River, Wyoming.

Skinner, Q.D. and T. A. Wesche. 1989. Evaluation of an Alternative Conveyance Strategy for Municipal Water.

Wesche, T.A. and Y.K. Tung. 1989. Snowy Range Observatory: Maintenance and Evaluation.

Marcus, M.D. 1989. Limnological Properties of a Rocky Mountain Headwater Reservoir. Water Resources Bulletin, 25(1): 15-25.

Henszey, R.J., T.A. Wesche and Q.D. Skinner. 1989. Evaluation of the State-of-the-Art Streambank Stabilization. Report prepared for the Water Quality Division, Wyoming Department of Environmental Quality.

Tung, Y.K., Y. Bao and V.R. Hasfurther. 1989. Selecting Appropriate Flood Design Frequencies for Drainage Basins in Wyoming. Interim Final Report to the Wyoming Highway Department. 119 p.

Adams, J.C., M.S. Lytle, D.G. Dickman, D.H. Foster, J.P. Connell and W.R. Bressler. 1989. Comparison of Methods for Enumeration of Selected Coliforms Exposed to Ozone. Applied and Environmental Microbiology, 55(1): 33-35.

SERVICE ACTIVITIES

Water Resources Data System

The Water Resources Data System (WRDS) is a computerized data storage and analysis system housing the largest single repository of hydrological and climatological data for the State of Wyoming. WRDS databases include: surface water quantity, water quality, climate, well levels, and snow course.

WRDS is set up primarily to assist state agencies; however, the service is also provided to federal, county, and municipal agencies, as well as university faculty, private firms and citizens. Requests are made for database retrievals, data loading, mapping and graphics, statistical analysis, limited custom programming, and accessing other data systems.

The Wyoming State Engineer's Office provides funds in the amount of $70,000 annually through a service contract with the Wyoming Water Research Center.

Wyoming Water Bibliography

As part of the Water Resources Data System, the WWRC continues to work with the State Library in Cheyenne to provide search and retrieval on the Wyoming Water Bibliography (WWB) for state agencies in addition to updating the database itself with state documents. This service project originated at the request of the Governor's Office and has grown to become the most comprehensive, multidisciplinary, computer-based bibliographic storage and retrieval system regarding Wyoming's water resources. The WWB contains approximately 13,000 citations.

COOPERATIVE ARRANGEMENTS

ADMINISTRATION

As specified in its charter, the Wyoming Water Research Center has responsibility for 1) Service, 2) Extension, 3) Research, and 4) Instruction. The Director, in keeping with the Center's charter, and in cooperation with the State of Wyoming, has spent the majority of his time in organizing the following services.

1. **Service:**

Service to State Agencies

- Continual liaison with state agency officials. Table 1 lists cooperating state agencies and Table 2 lists specific projects performed in response to state requests.
- Basic technology transfer to state agencies and Wyoming water users and managers.
- Serve as advisor to Wyoming Water Development Commission and review proposals for work from consultants.
- Continued attempts to integrate state and federal research programs.
- Interaction with State Legislature subcommittees (i.e., Select Water Committee).
- Participate in Governor's Selenium Work Group.
- Attend Governor's Water Forum.
- Attend meetings regarding specific research projects.

University Service

- Member, University of Wyoming Deans Council.
- Serve on University committees.
- Continued effort to apprise faculty members of research needs and opportunities in water-related research.

TABLE 1: COOPERATING AGENCIES IN WYOMING

STATE:

Attorney General's Office
State Conservation Commission
Department of Agriculture
Department of Environmental Quality
  Air, Land & Water Quality Divisions
Disaster and Civil Defense
Economic Development & Stabilization Board
Game & Fish Department
Governor's Office
Highway Department
Industrial Siting Administration
Legislative Services Office
Oil & Gas Conservation Commission
Recreation Commission
State Climatologist
State Engineer's Office
State Planning Coordinator's Office
Travel Commission
Water Development Commission
Wyoming Geological Survey

FEDERAL:

U.S. Geological Survey
U.S. Department of Energy
U.S. Soil Conservation Service
U.S. Bureau of Reclamation
U.S. Forest Service
U.S. Bureau of Land Management
U.S. Fish and Wildlife Service
Environmental Protection Agency
Office of Surface Mining

TABLE 2. SERVICE-TO-STATE - FY1988

- Evaluate the Performance of Large Hay Bales for Bank Stabilization Purposes on the Upper Green River Through the Schwabacher Ranch

- Evaluation of Irrigation Diversions and Bank Storage Return Flows, Pinedale, Wyoming (Wyoming Water Development Commission and State Engineer's Office)

- Development of Methodology to Determine Flushing Flow Requirements for Channel Maintenance Purposes (Wyoming Water Development Commission, Wyoming Game and Fish, and U.S. Forest Service)

- Snowy Range Watershed Laboratory

- Riparian Zone Management, Muddy Creek, near Baggs, Wyoming (Ranchers, Water Quality Division of Department of Environmental Quality, U.S. Department of Agriculture, Bureau of Land Management, Soil Conservation Service)

- Enhancement of Aquatic/Riparian Ecosystems (Pole Mountain) (Wyoming Water Development Commission, Wyoming Game and Fish, and U.S. Forest Service)

- Climate Data Validation for Wyoming (State Engineer, Wyoming Water Development Commission and National Oceanic and Atmospheric Administration)

- Climatic Data Collection in Wyoming for Regional Climate Center in Lincoln, Nebraska (Farmers, Ranchers, Numerous State Agencies)

- Conveyance Losses in Natural Stream Channels (Wyoming Water Development Commission, State Engineer's Office, Board of Control)

- Water Resources Model Library - inventory of hydrologic and economic computer-based models (State Water Forum; i.e., all state and federal agencies in Wyoming involved in water)

- Compiling streamflow data for a portion of the State of Nebraska within the North Platte and Platte River Drainage (Wyoming State Engineer's Office, State Attorney General's Office)

TABLE 2. SERVICE-TO-STATE - FY1988 (cont.)

- Water Quality of Laramie's Water Supply (City of Laramie)
- Atmospheric Deposition Studies - Glacier Lakes Ecosystem Experiment Site (Rocky Mountain Forest and Range Experiment Station)

- Work with academic standards committee on Water Resources curriculum.
- Serve on appropriate graduate student committees.
- Serve on appropriate national and international technical review panels and committees.

Other

- Continued effort to be cognizant of regional and national water issues and research opportunities.
- Transfer of research results to appropriate users.

2. **Extension**

One of the four major missions of the WWRC involves extension activities. The WWRC believes in a strong water resources extension effort. The Associate Director for Extension and Information works in cooperation with the UW Agricultural Extension Service to develop expanded education programs among researchers conducting water-related research. It is our intention that both state and federal research results be packaged and presented in a useful and satisfactory manner to maximize the utilization of research effort and results.

Cokeville Elementary Research Project

In April, 1986, a researcher from the WWRC was invited to give a talk to a group of school children at Cokeville Elementary School in southwest Wyoming. The talk centered on scientific methods used in measuring weather and climate data (parameters), and subsequently resulted in a request by the students for hands-on experience in weather data collection.

A weather station (on loan from WWRC) which monitors precipitation and temperature data (minimum and maximum thermometers) was installed at the school during the summer of 1986. Data are continuing to be collected by the fifth and sixth grade students and submitted to the WWRC for input into the University of Wyoming mainframe computer. Simple listings of the data are generated, in addition to plots of the data over time. All output is returned to the students.

Data generated from this station are also used to describe local weather conditions for the residents. The local Soil Conservation Service office helps maintain the station.

3. **Research**

- Federal Program FY88

Research accomplishments of the FY88 Federal Water Research Program were reviewed by the Director. The results of the projects sponsored with the FY88 monies have been provided to the Center's advisory committees and presented at professional meetings.

- Federal Program FY89

The Director solicited proposals under the FY89 Federal Water Research Program from interested faculty on campus and the seven community colleges. Proposals were received and reviewed by state agencies and regional Water Institute/ Centers--four were funded under the program; two were funded from state funds as match.

4. **Instruction**

The Wyoming Water Research Center is cooperating with academic departments throughout the campus to provide master of science degree programs which contain high quality multi-disciplinary training in water resources. The master of science degrees offered through these affiliations are awarded as specialty options within the existing master of science programs currently housed within the sponsoring departments. The water resources emphasis will be acknowledged on the graduate transcript and thereby certify to potential employers that the candidate has completed an attractive, in-depth, multidisciplinary-course program in the broad area of water resources. There are 15 students enrolled in the program at present.

STATE CLIMATOLOGIST

The State Climatologist is housed within the Wyoming Water Research Center. The individual is expected to serve the public and the Wyoming Water Research Center by directing existing statewide climatological programs and services and by assisting academic researchers involved with meteorology-related work.

SOIL CONSERVATION SERVICE

The WWRC has an agreement with the Soil Conservation Service permitting access to the Centralized Forecasting System (CFS) in Portland, Oregon by WRDS personnel via microcomputer and modem. A computer account has been

established on the SCS mainframe for WRDS use and has been accessed regularly in responding to requests for data during the year. Additionally, the system has proved to be a valuable source of information to WWRC researchers and staff.

NATIONAL WATER DATA EXCHANGE

The WWRC serves as an assistance center for the National Water Data Exchange (NAWDEX) through a cooperative agreement for the purpose of helping users of water data identify and locate the data they need. The Center has access to several different data systems, including the Centralized Forecasting System (CFS) of the Soil Conservation Service; the Water Storage and Retrieval System (WATSTORE) and the Earth Science Data Directory (ESDD), both of the U.S. Geological Survey; the Storage and Retrieval System (STORET) of the U.S. Environmental Protection Agency; and the NAWDEX System itself.

WWRC ADVISORY STRUCTURE

The organizational structure and operational procedures of the WWRC for a high degree of accountability and relevance to state and regional water research seems to be working well. In 1982, the WWRC was restructured to include a Research Review and Priorities Committee (RRPC) appointed by the Governor of the State of Wyoming and the President of the University of Wyoming. The membership was designed to reflect the interests and inputs of the Executive Office,

the legislative branch of government, the academic community and the University administration (Table 3). The Committee meets at least twice annually to discuss WWRC activities and research priorities and to approve projects presented.

Prior to presentation of projects to the Advisory Committee, a review process that includes relevant state agencies, in addition to scientific peer review, has been completed. This process has insured good science directed toward issues meaningful to water research needs in the state and the region.

A Citizens Water Issues Advisory Council (CWIAC) was formed in January 1984 and consists of members selected by the Governor (Table 4). The council was formulated to represent a) agriculture, b) recreation, c) municipalities, d) National Forest Service, Bureau of Land Management, Bureau of Reclamation, U.S. Fish and Wildlife Service, e) consulting engineers, f) State Legislature, g) industry, h) environmental interests, i) private citizens, j) legal profession, k) political action groups (e.g., League of Women Voters), l) Wyoming Higher Education System, and m) state agencies. The Council is charged with collecting input from constituencies, water experts within and outside the State, and other available sources, identifying water concerns and transmitting those concerns to the Research Review and Priorities Committee. The Council meets at least once a year.

TABLE 3

WYOMING WATER RESEARCH CENTER

RESEARCH REVIEW & PRIORITIES COMMITTEE

January, 1988

Governor Mike Sullivan
(ex officio)
State Capitol Building
Cheyenne, WY 82002
777-7434

Governor's Appointees:

Paul Schwieger
(Chairman) (1983-1989)
Economic Development &
Stabilization Board
Water Division
Herschler Building
Cheyenne, WY 82002
777-7284

Rick Miller
State Planning Coordinator[1]
Herschler Building
Cheyenne, WY 82002
777-7574

Myron Goodson (1988-1991)
Wyo. Water Development Commission
Box 429
Sundance, WY 82729
283-2407

Patrick O'Toole
Wyoming House of Representatives[1]
Box 26
Savery, WY 82332
383-2418

Richard Larson
Wyoming Senate[1]
Box 1
Albin, WY 82050
246-3435

President Terry P. Roark
(ex officio)
Office of the President
University of Wyoming
766-4121

UW President's Appointees:

Steven P. Gloss (Exec. Sec.)
Director
Wyoming Water Research Center
13th and Lewis
University of Wyoming
766-2143

Ralph DeVries
Vice President for Research[1]
Old Main
University of Wyoming
766-5353

Bill Gern (1988-1991)
Zoology & Physiology Dept.
Biological Sciences Building
University of Wyoming
766-4207

Quentin Skinner (1985-1988)
Range Management Department
Agriculture Bldg., Rm. 2028
University of Wyoming
766-4139

---

[1]Designated member of RRPC by Charter of WWRC.

TABLE 4

WYOMING WATER RESEARCH CENTER

CITIZENS WATER ISSUES ADVISORY COUNCIL

January, 1988

Walter Yose, Jr.
P.O. Box 94
LaBarge, WY 83123
386-2322

Russell Michael
Route #2
Torrington, WY 82240
788-1139

Jim Noble
Box 80
Cora, WY 82925
367-4553

Tom Hill
P.O. Box 6132
Laramie, WY 82070
745-3136

Cynthia Nunley
864 N. 4th
Lander, WY 82520
332-2442

David Park
120 West 1st, Suite 300
Casper, WY 82601
234-3756

John Morris
10401 Experimental Farm Road
Cheyenne, WY 82009
634-7561

Beryl Churchill, Chairperson
RR3, 848 Road 10
Powell, WY 82435
754-4865

Steve F. Adams
Box 177
Baggs, WY 82321
324-7876

Doyl M. Fritz
Western Water Consultants, Inc.
Box 3016
Sheridan, WY 82801
672-0761

Dick Brown, Vice President
Pacific Power and Light Co.
P.O. Box 720
Casper, WY 82602
577-6901

Larry Wolfe
Holland and Hart
2020 Carey Avenue, Suite 500
Cheyenne, WY 82001
632-2160

TRAINING ACCOMPLISHMENTS

Shown by fields of study and training levels indicated, the number of students participating in projects financed in part through the Fiscal Year 1988 Program are indicated below.

Training Category	Academic Level				
		Graduate			
Field of Study	Under-Graduate	Master's Degree	Ph.D. Degree	Post-Ph.D.	Total
Chemistry					
Engineering					
Agricultural					
Civil					
Environmental					
Geology		1			1
Hydrology	1				1
Agronomy					
Biology					
Ecology					
Fisheries, Wildlife and Forestry (Zoology)		1			1
Computer Science					
Economics	1				1
Geography					
Law					
Resources Planning					
Range Management		1			1
Other - specify					
Environmental Toxicology	2	1			3
TOTAL	4	4			8