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Wyoming Water Research Center
University of Wyoming
Laramie, WY 82071

Steven P. Gloss, Director

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ABSTRACT

Six research projects were funded under the FY87 program, as well as an information transfer program. A short statement identifying each project follows:

A field lysimeter study near Laramie, Wyoming was conducted to measure phreatophyte transpiration utilizing porometry and a weighing lysimeter. Data collected indicated that seasonal evapotranspiration estimates were in close agreement between porometry and weighing lysimeter data.

Four techniques were evaluated for measuring intragravel water velocity (IWV) in five different compositions of salmonid substrate material. It was found that none of the four techniques could be recommended for field measurement of IWV in these substrate materials.

A Paleozoic Aquifer of the Casper Formation was identified as a potential untapped groundwater source in Laramie County, Wyoming. Recharge investigations were conducted along a possible recharge boundary of the aquifer to try and quantify the recharge amount. It was found that the study area is hydraulically severed by a thrust zone from the rest of the aquifer, but a possible area of recharge was identified north of the study area.

The impact of sedimentation and resulting spring flushing flows on the sediment were evaluated as to their effects on aquatic macroinvertebrates of a high mountain stream. The results indicated that a significant sediment impact on a high mountain stream did not adversely affect the aquatic microinvertebrate population for any significant time period.

Factors influencing upland sediment and runoff production were studied on a north-central Wyoming watershed which produces approximately 75 percent of the suspended sediment load to the Bighorn River. The factors found to be most important were slope gradient, vegetation-density and soil texture.

A multiobjective decision-making approach was utilized to develop a waste load allocation management model for a stream. The use of multi-objective analysis revealed that useful information can be gained for effective water quality management decision making.

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.

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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' experience 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 complimentary 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 step-wise 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 1987

STATE OF WYOMING RESEARCH PRIORITIES												
	Ground & Surface Water Resources			Watershed & Riparian Zone Management					Water Development & Conservation			
RESEARCH PROJECTS FY87	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 - A Comparison of Two Methods for Measuring Phreatophyte Transpiration: Porometry and Weighing Lysimeter	X			X				X				
Project #03 - Evaluation of Procedures to Measure Intragravel Flow in Streambeds		X				X					X	
Project #04 - Stream Aquifer Interaction as a Possible Source of Recharge to the Paleozoic Aquifer Along the Laramie Mountains, Laramie County, Wyoming	X			X								

FIGURE 1

STATE OF WYOMING RESEARCH PRIORITIES AND PROJECTS

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Fiscal Year 1987

STATE OF WYOMING RESEARCH PRIORITIES												
	Ground & Surface Water Resources			Watershed & Riparian Zone Management					Water Development & Conservation			
RESEARCH PROJECTS FY87	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 - Impact of Sedimentation on the Aquatic Macroinvertebrates of the North Fork of the Little Snake River						X		X			X	
Project #06 - Effect of Terrain Type, Channel Morphology, and Watershed Morphometry on Natural Production of Sediment	X	X				X	X					
Project #07 - Multiobjective Water Quality Management of Stream Environment		X	X									

FIGURE 2

FEDERAL RESEARCH PRIORITIES AND PROJECTS

FUNDED BY USGS THROUGH THE WYOMING WATER RESEARCH CENTER

Fiscal Year 1987

	FEDERAL RESEARCH PRIORITIES								
	Water Quantity		Water Quality	Institutional Relations	Utilization and Conservation of Water		Ecological/Environmental Relationships		
RESEARCH PROJECTS FY87	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 - A Comparison of Two Methods for Measuring Phreatophyte Transpiration: Porometry and Weighing Lysimeter		X			X	X			
Project #03 - Evaluation of Procedures to Measure Intragravel Flow in Streambeds		X					X		
Project #04 - Stream Aquifer Interaction as a Possible Source of Recharge to the Paleozoic Aquifer Along the Laramie Mountains, Laramie County, Wyoming		X							

FIGURE 2

FEDERAL RESEARCH PRIORITIES AND PROJECTS

FUNDED BY USGS THROUGH THE WYOMING WATER RESEARCH CENTER

Fiscal Year 1987

	FEDERAL RESEARCH PRIORITIES								
	Water Quantity		Water Quality	Institutional Relations	Utilization and Conservation of Water		Ecological/Environmental Relationships		
RESEARCH PROJECTS FY87	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 - Impact of Sedimentation on the Aquatic Macroinvertebrates of the North Fork of the Little Snake River			X						X
Project #06 - Effect of Terrain Type, Channel Morphology and Watershed Morphometry on Natural Production of Sediment		X	X						X
Project #07 - Multiobjective Water Quality Management of Stream Environment			X	X		X			X

RESEARCH PROJECT SYNOPSES

SYNOPSIS

Project Number: 02

Start: 6/1/87
End: 5/31/88

Title: A Comparison of Two Methods for Measuring Phreatophyte Transpiration: Porometry and Weighing Lysimeter

Investigators: J.R. Foster, L. Pochop, R. Burman, University of Wyoming, Laramie

COWRR: 02D

Congressional District: One

Descriptors: transpiration, evapotranspiration, willow, Salix, riparian zone, lysimeter, porometer

Problem and research objectives:

Existing methods (e.g. non-weighing and weighing lysimeters) for measuring riparian transpiration are cumbersome and expensive. Recent research has shown the feasibility of using direct measurements of transpiration rates of individual leaves (porometry) to calculate phreatophyte water use. This method has potential for rapid, replicable estimation of riparian zone water use. However, independent calibration using an alternative method with good temporal resolution is highly desirable to test the validity of the assumptions used when extrapolating from individual leaves to whole-canopy water use and for extrapolating from daily to seasonal estimates.

The purpose of this research was to compare the transpirational water use by willow transplants within a riparian zone in a semiarid, montane basin in Wyoming as independently and simultaneously estimated by an existing weighing lysimeter and with a diffusion porometer.

Methodology:

The study was conducted on the floodplain of the Big Laramie River, 3 km southwest of Laramie at the site of a recently installed sensitive weighing lysimeter. The lysimeter was 1.05 m in diameter by 1.37 m deep with load cells used to detect weight changes. In late June of 1987, five whole clumps of sandbar willow were transplanted to the lysimeter from an open willow stand adjacent to an irrigation ditch about 0.5 km from the study site. A layer of gravel 10 cm deep was placed on top of the soil, flush with the lysimeter rim, to minimize soil evaporation.

To further define the evaporation component of the total water loss measured by the lysimeter, two weighable bucket lysimeters measuring 30 cm in diameter and 1.37 cm deep were installed adjacent to the weighing lysimeter. These were installed and operated with a gravel mulch and water table similar to the weighing lysimeter but without the willows. Thus, water losses from the bucket lysimeters provided an estimate of the evaporation component.

Diurnal transpiration curves were developed from hourly porometer measurements for selected days during the summer. Dawn to dusk porometer measurements were taken during eleven days in July, August, and September while measurements were continued throughout the nocturnal period for one day each in July and August.

Supplementary measurements of climatic parameters and soil temperature were obtained on a continuous basis during the study period using a Campbell-Scientific automated weather station. The climatic data were used to estimate diurnal and total daily potential evapotranspiration. The data logger of the weather station was also used to record the weighing lysimeter measurements.

Extensive calibration of the weighing lysimeter indicated a lack of necessary precision for obtaining hourly evapotranspiration measurements. Daily (midnight to midnight) measurements for 49 days and the total water use were obtained from the weighing lysimeter for the study period July 20 through September 22, 1987. Total water use was estimated by summing the values for the 49 days having measurements and using linear interpolation for the remaining days. Cumulative seasonal evapotranspiration was interpolated for non-measured days. Porometer transpiration values were divided by 0.76 to account for soil evaporation, based on the bucket lysimeter data.

Principal findings and significance:

Comparisons of cumulative seasonal evapotranspiration estimates for the 65-day measurement period gave close agreement between porometer and lysimeter data. Estimated seasonal values were 224 kg for the weighing lysimeter versus 240 kg for the porometer transpiration plus evaporation. The latter value of 240 kg is about 7 percent greater than the weighing lysimeter total of 224 kg. No correction for nocturnal transpiration was applied, although on some nights measurable transpiration probably occurred.

Unfortunately, lysimeter data were either missing or erratic during six of the eleven days when transpiration was estimated by porometry. Because of this, and because of the low precision of the daily lysimeter data, no attempt was made to compare daily lysimetry and porometry transpiration estimates.

Publications and professional presentations:

None.

M.S. theses:

Students supported on this project included Terry Henkel, a M.S. graduate student in Botany, and Scott Boelman, a B.S. student in Agricultural Engineering, both at the University of Wyoming. Terry Henkel is currently completing a M.S. thesis in Botany concerning porometry, but not directly based on this project. Scott Boelman received a B.S. in Agricultural Engineering in December, 1987, and

is currently a M.S. student in Civil Engineering at the University of Wyoming.

Ph.D. dissertations:

None.

SYNOPSIS

Project Number: 03

Start: 6/1/87
End: 5/31/88

Title: Evaluation of Procedures to Measure Intragravel Flow in Streambeds

Investigators: V.R. Hasfurther, T.A. Wesche, W. Hubert, University of Wyoming, Laramie

COWRR: 05C

Congressional District: One

Descriptors: Intragravel flow, porous media, sediment, stream, water quality, fish habitat

Problem and research objectives:

Water flowing through streambed gravels is the medium in which salmonid embryos incubate. The velocity of this intragravel water near the embryos has been linked to their survival and condition (Turnpenny and Williams 1980; Sowden and Power 1985). Intragravel water velocity (IWV) is influenced by sediment deposition (Wickett 1954) and dewatering (Reiser and White 1981); therefore, field measurement of IWV may be useful in assessing the impacts of sedimentation and dewatering on salmonid embryos, and may also be useful in predicting embryo survival under natural conditions.

Forty years of research have failed to produce a standard method for measurement of IWV, but several techniques have been tried or proposed. The tracer dilution technique was first published by Wickett (1954), and then modified into the Mark VI standpipe technique by Terhune (1958). The Mark VI technique remains virtually unchanged, and is probably the most commonly used IWV measurement technique to date (Reiser and White, 1981). Terhune (1958) suggested remarkable precision in laboratory tests, but he was not using natural streambed substrates. A dilution technique that used a salt solution was designed by Turnpenny and Williams (1982) and modified by Carling (1986). Measuring time-of-travel of various tracers in water is a common technique for determining surface water velocity and groundwater movement, but it has not been used specifically to measure IWV, and may have application. Techniques used to calculate IWV indirectly include the mini-piezometer (Lee and Cherry 1978) - a plastic tube inserted into the gravel to measure hydraulic head and permeability - and the method of Bovee and Cochnauer (1977) using measurements of permeability and surface water characteristics.

The goal of this project was to identify an accurate, inexpensive, and reliable technique to measure IWV in natural streambeds and salmonid redds. The specific objectives were:

1. to evaluate the performance of new and existing IWV measurement techniques under laboratory and field conditions in terms of their accuracy, precision, cost-effectiveness, and applicability, and
2. to recommend standard IWV measurement procedures for use by managers and researchers.

Methodology:

Existing and potential IWV measurement techniques were examined through an extensive literature review. Four techniques were evaluated during a series of tests in open trough permeameters, a laboratory flume and in the field. These included the Mark VI dye definition technique (Terhune 1958), time-of-travel methods using fluorescent dyes and saline solutions, mini-piezometers (Lee and Cherry 1978), and a method based upon characteristics of the surface flow (Bovee and Cochnauer 1977).

The first three techniques were evaluated in open-trough, horizontal-flow permeameters constructed of 13 mm plexiglass to hold a substrate bed obtained from alluvial deposits of the Laramie River. The permeameters measure 67 cm long, 50 cm wide, and 33 cm deep. Five different compositions of substrate material were used in the permeameters. A screen of 6.3 mm mesh hardware cloth and 0.33 mm mesh polypropylene screen held the substrate in place. Baffles around the inflow and outflow standpipes promoted even flow through the substrate bed, and piezometers installed on the permeameter wall allowed measurement of water level in the substrate. IWV through the gravel bed was calculated by determining discharge and dividing by the water cross-sectional area.

The fourth method of Bovee and Cochnauer (1977) using surface water characteristics was evaluated in a concrete flume (91 cm wide and deep by 21.3 m long) and compared with Mark VI dye dilution rates. IWV was calculated using both an assumed Manning's n of 0.035 (Bovee and Cochnauer 1977) and a Manning's n calculated from hydraulic measurements. These values were compared with both Mark VI dye dilution rates and the IWV values derived from Terhune's (1958) calibration curves.

Principal findings and significance:

The Mark VI dye dilution technique (Terhune 1958) was correlated ($P < 0.05$) with IWV, but its precision was insufficient to consistently distinguish between IWV's of 0-50 cm/h. Time-of-travel techniques demonstrated potential for measurement of undisturbed substrate, but were not reliable in field conditions. Calculations with mini-piezometers (Lee and Cherry, 1978) were not correlated with IWV, and the method of Bovee and Cochnauer (1977) was not correlated with IWV estimated by Mark VI dye dilution. Due to measurement imprecision, natural variability within the bed material, and problems with measurement equipment and procedures, field measurement of IWV is not recommended for monitoring the incubation environment of salmonid embryos by natural resource managers and researchers.

References:

Bovee, K.D. and T. Cochnauer. 1977. Development and evaluation of weighted criteria, probability-of-use curves for instream flow assessments: fisheries. Cooperative Instream Flow Service Group, Fort Collins, Colorado. FWS/OBS-77/63. Instream Flow Information Paper No. 3.

Carling, P.A., and P. Boole. 1986. An improved conductiometric standpipe technique for measuring interstitial seepage velocities. Hydrobiologia 135:3-8.

Lee, D.R. and J.A. Cherry. 1978. A field exercise on groundwater flow using seepage meters and mini-piezometers. Journal of Geological Education 27:6-10.

Reiser, D.W. and R.G. White. 1981. Influence of streamflow reductions on salmonid embryo development and fry quality. Idaho Water and Energy Resources Research Institute, University of Idaho. Research Technical Completion Report Project A-058-IDA.

Sowden, T.K. and G. Power. 1985. Prediction of rainbow trout embryo survival in relation to groundwater seepage and particle size of spawning substrates. Transactions of the American Fisheries Society 114:804-812.

Terhune, L.D.B. 1958. The Mark VI groundwater standpipe for measuring seepage through salmon spawning gravel. Journal of the Fisheries Research Board of Canada 15:1027-1063.

Turnpenny, A.W.H. and R. Williams. 1980. Effects of sedimentation on the gravels of an industrial river system. Journal of Fish Biology 17:681-693.

Turnpenny, A.W.H. and R. Williams. 1982. A conductiometric technique for measuring the water velocity in salmonid spawning beds. Water Research 16:1383-1390.

Wickett, W.P. 1954. The oxygen supply to salmon eggs in spawning beds. Journal of the Fisheries Research Board of Canada 11:933-953.

Publications and professional presentations:

Grost, R.T., T.A. Wesche, M.K. Young, W.A. Hubert and V.R. Hasfurther. 1988. Evaluation of procedures to measure intragravel water velocity in streambeds. Draft manuscript to be submitted to North American Journal of Fisheries Management.

M.S. theses:

Results of this study will serve as a portion of Richard Grost's M.S. thesis in Zoology/Water Resources, University of Wyoming, 1989.

Ph.D. dissertations:

Results of this study will serve as a portion of Michael Young's Ph.D. dissertation in Zoology/Physiology, University of Wyoming, 1990.

Students supported on project:

Graduate - 2

Undergraduate - 3

SYNOPSIS

Project Number: 04

Start: 5/15/85
End: 5/31/88

Title: Stream-Aquifer Interaction as a Possible Source of Recharge to the Paleozoic Aquifer Along the Laramie Mountains, Laramie County, Wyoming

Investigators: V.R. Hasfurther and G.L. Kerr, University of Wyoming, Laramie

COWRR: 02A

Congressional District: One

Descriptors: surface-groundwater relationships, natural recharge, seepage, aquifer characteristics, hydrologic properties

Problem and research objectives:

The Paleozoic aquifer, comprised chiefly of the Casper Formation, has been identified as a potential water resource in Laramie County, Wyoming. Prior to any commitments for development, further information is needed to characterize the hydrologic system. Included in this characterization are the quantification of ground-water flow parameters, such as hydraulic conductivity and gradient, estimation of natural recharge to and discharge from the aquifer, and evaluation of water quality. The focus of this study was to determine the quantity of recharge the Paleozoic aquifer receives where perennial streams cross the aquifer outcrop along the east flank of the Laramie Mountains, examine water quality differences between surface and ground waters in the recharge area, determine the importance of stream losses as recharge to the Paleozoic aquifer at other selected localities along the mountain front, and characterize the regional nature of the Paleozoic aquifer in the Denver-Julesburg Basin.

Methodology:

The study site was located in western Laramie County, where the North Fork of Horse Creek crosses the Paleozoic aquifer outcrop. Hydrologic data collected for this study included: precipitation at the study reach and in the upper basin area, stream stage and discharge above and below the study reach, and shallow ground-water levels near the lower end of the stream reach. Discharge data were recorded from two servo-manometer bubble gages and two nine-inch Parshall flumes installed above and below the study reach along with two 3-inch flumes installed at intermediate points. Water balance calculations were performed using the hydrologic data collected at the site to determine recharge to the aquifer.

Water quality analyses were performed on a quarterly basis by sampling the groundwater wells and the stream itself. Water quality data were then compared to determine interaction between the groundwater and the surface waters within the study area.

Determining the importance of stream losses as recharge to the Paleozoic aquifer at other selected localities along the mountain front was achieved by studying aerial photos of selected streams and by field observations. Three geologic maps were developed from aerial photos and extensive field investigation in order to characterize the regional nature of the Paleozoic aquifer in the Denver-Julesburg Basin.

Principal findings and significance:

From the water budget analysis conducted on the North Fork of Horse Creek, it was determined that no significant recharge to the Paleozoic rocks occurred along the study reach. From the period July 1987 to May 1988, the water budget analysis indicated a small total loss in streamflow during 5 of the 11 months. The minimal amount of water lost was determined to be recharge to the shallow alluvium in the lower section of the study reach and to possible increased evaporation due to excessive high winds in the canyon area of the study reach. Water quality analysis results indicated a direct relationship between the shallow alluvium and the stream. Comparison of water quality analysis between the shallow alluvium and the deeper layer below, believed to be in the Muddy Sandstone, did not give any indication of interaction between these two areas.

These results were considered to be representative of all other streams in the study area which flow across outcrops of Paleozoic rocks in a structural environment similar to that along the North Fork of Horse Creek. Additional stream gaging on other streams in the study area was determined to be unnecessary due to the following reasons. All but two of these streams flow through parts of the recharge area which are severed from the rest of the basin by thrust faults. These faults are impermeable boundaries which effectively prohibit any recharge from these streams from reaching the basin interior. The two streams which do flow through parts of the recharge area, which are apparently in hydraulic communication with the rest of the aquifer, are the North Fork of Horse Creek and Mill Creek. The North Fork of Horse Creek was gaged in detail for the water budget analysis. Mill Creek, which is the next stream to the south of the North Fork of Horse Creek, flows over Paleozoic rocks which were heavily involved in the limestone mine on the adjacent hogback. Mining practices are believed to have altered in the hydrologic characteristics of these rocks to such an extent as to render the results of any gaging of this stream unique to this one circumstance and, therefore, of limited interest to this study.

In order to learn if recharge to the Paleozoic aquifer can circulate from the recharge area to the basin interior, the geologic framework was examined in conjunction with the shape of the potentiometric surface. This was accomplished with the development of three maps: (1) a detailed tectonic map of the recharge area along the east flank of the Laramie Range; (2) a structure contour map of the basin interior adjacent to the recharge area; and (3) a potentiometric map of the same area covered by the structure contour map. Also involved was the identification of hydrologically isolated compartments within the aquifer which influence groundwater circulation.

These efforts resulted in the following conclusions. The recharge area, from Horse Creek to the southern border of the study area is hydraulically severed from the rest of the aquifer by an impermeable thrust zone. This thrust zone effectively prohibits recharge from circulating to the basin interior. The recharge area to the north of Horse Creek does not appear to be separated from the rest of the aquifer. Conceivably, recharge could circulate to the basin interior under the influence of a hydraulic gradient which trends east-southeast.

Grossly under-pressured compartments were identified within the Muddy Sandstone which are hydrologically isolated from the rest of the aquifer. The seals which separate these compartments from the rest of the aquifer also act as impermeable boundaries around which groundwater must flow. No significant evidence could be found to indicate either the presence or absence of such compartments in the Paleozoic aquifer.

Publications and professional presentations:

Mizell, S.A., U.M. Wiersma and G.L. Kerr. 1987. Stream-Aquifer Interaction as a Possible Source of Recharge to the Paleozoic Aquifer Along the East Flank of the Laramie Range, Laramie County, Wyoming: Second Annual Report. Report to the Wyoming Water Research Center (USGS G1262-04), University of Wyoming, Laramie.

Mizell, S.A., U.M. Wiersma and G.L. Kerr. 1986. Stream-Aquifer Interaction as a Possible Source of Recharge to the Paleozoic Aquifer Along the East Flank of the Laramie Range, Laramie County, Wyoming: First Annual Report. Report to the Wyoming Water Research Center (USGS G1065-04), University of Wyoming, Laramie.

M.S. theses:

Wiersma, Ursula M. Examination of the Evidence for Recharge to the Paleozoic Aquifer Along the East Flank of the Laramie Range, Laramie County, Wyoming. University of Wyoming, Laramie. (Expected completion date: Fall 1988.)

Ph.D. dissertations:

None.

SYNOPSIS

Project Number: 05

Start: 6/1/87
End: 5/31/88

Title: Impact of Sedimentation on the Aquatic Macroinvertebrates of the North Fork of the Little Snake River

Investigator: J.A. Lockwood, University of Wyoming, Laramie

COWRR: 05C

Congressional District: One

Descriptors: Biotic Condition Index, sediment, aquatic insects, scouring, composition, ecology, pollution

Problem and research objectives:

The North Fork of the Little Snake River (North Fork) is a steep, rough, regulated headwater stream located in the Colorado River basin in southwest and south-central Wyoming. A water development project, the Cheyenne Stage II Diversion Project began in 1983 in an effort to collect 23,000 acre feet of water annually from 30 tributaries of the North Fork for the City of Cheyenne, Wyoming. The North Fork and its tributaries support the largest known, essentially pure population of the Colorado River Cutthroat trout, (Salmo clarki pleuriticus Cope). This species is classified as "Sensitive" in Wyoming.

Earlier work on the effects of Stage I of the Cheyenne Diversion Project demonstrated that the Colorado River cutthroat standing crop had been reduced to 37 percent of its former levels. While the factors resulting in this impact were not independently analyzed, it was recommended that monitoring the impact of construction of roads, pipelines, and diversion structures should emphasize the potential damage caused by increased sediment on fish and macroinvertebrate populations. This recommendation appears to be well-founded based on studies which have demonstrated that aquatic insects are sensitive and reliable indicators of sedimentary pollution and stream quality.

During the late summer of 1984, intensive rainfall in the construction area resulted in the deposition of a broad size range of sediments into the North Fork. The introduction of this sediment into the North Fork presented an excellent opportunity to study the impacts of sedimentation and flushing flows on the aquatic macroinvertebrates in the North Fork.

Funds received from the Wyoming Water Research Center beginning in July 1985, which continued with USGS funds through September 1987, resulted in collection of the necessary aquatic macroinvertebrate community for assessing the impact of the addition of this sediment on that community. To best ascertain the degree of impact on the North Fork, the objectives of the study were to: 1) describe the changes in selected biological indices (diversity, evenness, richness and abundance) between impacted and non-impacted sites, 2) determine the preferences of the aquatic macroinvertebrate taxa for selected substrate sizes,

3) determine the preferences of the aquatic macroinvertebrate taxa for mean water velocity, and 4) determine the preference of the aquatic macroinvertebrate taxa for water depth.

Methodology:

The study locations consisted of two control sites above, and seven potentially impacted sites below the Cheyenne Diversion Project. At each site, six representative samples were taken using a 0.02 inch mesh Surber sampler each month from June to September, over a three-year period beginning in 1985 for a total of 480 collections. The larger rocks and rubble were washed off in front of the net using the current to sweep the aquatic insects into the net. Smaller gravels, sand, and silt were stirred for 10-15 sec. washing any remaining insects into the net. All larger rocks were then measured along their longest dimension, and mean rock size for the individual samples was determined. Substrate size was classified as to whether the sample was composed mainly of sand, gravel, rubble or boulder. In June, July and September of 1987, each family that comprised at least 5 percent of the community associated with each substrate was classified as to substrate preference. During the July and September collecting period for 1987, water depth and velocity were recorded for each sample at each site using a Marsh-McBirney Model 201 Current Meter attached to a depth rod. Water velocity was recorded at 0.6 the water depth. A total of 102 water depth and velocity samples were taken. Water depth and velocity preferences were calculated for the orders Ephemeroptera, Plecoptera, Trichoptera, Diptera, and Coleoptera for the months of July and September.

Benthic organisms collected in the field were preserved in 70 percent ethanol. In the laboratory the organisms were picked from the debris under a binocular dissecting scope. After all the samples were picked, they were then identified to the most specific level of available expertise.

The Shannon (base 10) index of diversity, Shannon index of evenness, total number of taxa, and total number of individuals were computed.

Principal findings and significance:

For the years 1985, 1986, and 1987, the general trend was for diversity, richness and evenness to increase from June or July through September. As the season progressed, there was an increase in the number of families represented. Also, as the summer progressed, the proportion of dominant families decreased because of emergence.

Abundance and richness showed a marked decrease in 1986. There appears to be a function of erratic water flow releases from the diversion structures in 1986. The site of heaviest sediment impact reflected the same general trends as all the other sites. For this site, all representative families were present for all three years. This site had the lowest measure of abundance for all sites for all years. This appears to be a function of the erratic hydrograph for 1986 compounded by an unstable substrate (sand).

For the North Fork, Ephemeroptera, Plecoptera, Trichoptera and Diptera contributed the majority of total macroinvertebrate density, although Coleoptera was well represented by the family Elmidae. For all years, Ephemeroptera was the dominant order with the families Heptageniidae and Baetidae occurring in high numbers. When the orders of Plecoptera and Trichoptera appeared in high numbers, it appeared to be a function of finding high numbers of early instars. In the order Diptera, the family Chironomidae was quite prominent for all years at all sites.

In June, only a few of the families present in the North Fork showed either a preference for, or were well represented in, a sand substrate. However, the only families to utilize this substrate throughout the summer were Tipulidae and Chironomidae. The other families shifted from a sand to a gravel or rubble substrate in July and September. This is probably a function of life histories. By far, a gravel and/or rubble substrate had the larger numbers of macroinvertebrates when compared with sand or bedrock. For the present, it appears that most aquatic insects are substrate generalists. However, the substrate preferences for the aquatic macroinvertebrates in the North Fork shows a progressive increase in abundance from a sand to a rubble substrate, and then a decrease in total numbers when substrate size increases to bedrock.

Considering both water velocity and depth, for the aquatic invertebrates in the North Fork, the optimum condition for highest abundance would be in velocities of above 0.6 ft/s at a depth ranging from 0.2 to 1.0 ft.

Unfortunately, there was no assessment of the immediate impact of the large sediment loads deposited in the North Fork in 1984 on the aquatic macroinvertebrates. When this study began in July of 1985, the ecological indices suggested that the aquatic community, no matter how severely impacted, had recovered. The reason that there were no demonstrable impacts to the aquatic macroinvertebrates in the North Fork may include the following considerations: 1) the time lapse from the date of initial sediment impact to the first sample date, 2) the high springtime flow rates and flushing flows that removed sediment from the impacted area, 3) the presence of substrates that were not completely embedded and were able to serve as islands for the aquatic community, and 4) the presence of unimpacted upstream reaches that allowed for quick recolonization.

The use of flushing flows on the North Fork proved very effective in removing the finer sediment from the heavily impacted site. However, the decline in the ecological viability of the community in 1986, which was apparently caused by the fluctuating releases, is of some concern. Increases in discharge disturb the bed and may also increase sediment input which may have resulted in the displacement of the benthic populations.

When complete, the Cheyenne Stage II Diversion Project will alter the natural flows of the North Fork. From this study, it appears that with flushing flows between 50 and 105 cfs, the aquatic macroinvertebrates are not affected and these lower flows may even enhance the community

as opposed to discharges of up to 250 cfs which occurred naturally in 1986 which had a strong negative impact on the aquatic macroinvertebrates. From the data collected on water depth and velocity preference, the recommended minimum flow of 3.0 cfs for the North Fork is adequate for the aquatic insects. With proper timing of the flushes (accurately simulating spring runoff) it is felt that the flushing flows will preserve the North Fork as a suitable habitat for the Colorado Cutthroat trout and the aquatic insects. However, if improperly timed or mediated, these flows may seriously disrupt the macroinvertebrates and ultimately the trout.

Publications and professional presentations:

DeBrey, L.D. and J.A. Lockwood. 1988. Application of the biotic condition index to assessment of stream management practices. Entomological Society of America North Central Branch Meeting, Denver, Colorado.

DeBrey, L.D. and J.A. Lockwood. 1987. Impact of sediments on aquatic macroinvertebrates in a high mountain stream. Entomological Society of America National Meeting, Boston, Massachusetts.

DeBrey, L.D. and J.A. Lockwood. 1988. Mitigation of sediment damage by flushing flows to the aquatic macroinvertebrate community of a high mountain stream. Regulated Rivers (in preparation).

M.S. theses:

Impact of sedimentation on the aquatic macroinvertebrates of the North Fork of the Little Snake River. Larry D. DeBrey. University of Wyoming.

Ph.D. dissertations:

None.

SYNOPSIS

Project Number: 06

Start: 6/1/87
End: 5/31/88

Title: Effect of Terrain Type, Channel Morphology, and Watershed Morphometry on Natural Production of Sediment

Investigators: R.A. Marston, University of Wyoming, Laramie

COWRR: 02J

Congressional District: One

Descriptors: sediment production, runoff, nonpoint sources, rainfall simulation, computer assisted mapping, watershed morphometry, erosion response units, Fifteenmile Creek

Problem and research objectives:

The Fifteenmile Creek watershed in north-central Wyoming contributes only 0.8 percent of the mean annual flow to the Bighorn River, but 75 percent of the mean annual suspended sediment load. An expensive watershed improvement program was conducted by the Bureau of Land Management (BLM) in the 1950s and 1960s without a systematic understanding of the nonpoint sources of sediment and runoff. Sediment discharge was reduced 25 percent as of the late 1970s by the BLM efforts, but many sediment control structures have since failed. Future watershed improvement projects must be strategically located to prevent a waste of effort and financial resources.

The objectives of the research were to: 1) determine the factors that influence upland sediment and runoff production; 2) identify the relative contribution of sediment and runoff from various portions of the watershed; and 3) present the findings in such a way that they will compliment concurrent work on sediment production from the riparian zone of Fifteenmile Creek watershed.

Methodology:

To measure gross erosion and runoff under controlled field conditions, a rainfall simulator was constructed. A simulator was needed which: 1) could produce rainstorms with similar kinetic energy to natural rainfall events in the study area; 2) was portable (to overcome problems of difficult access to study sites); 3) had a low rate of water consumption (to overcome the problem of working in an arid region at sites far from turbidity-free water); 4) was easy to operate (to maximize sample size with minimal field personnel); and 5) could be used on steep slopes (which were suspected to produce the most sediment). The chosen design was based on the "Tahoe Basin" model rainfall simulator described in the literature. The design simulator used, based on the "Tahoe Basin" simulator, would produce 3.2 mm (0.127 in) diameter drops through polyethylene tubing. The drops fall 7.5 ft (2.286 m) to a 2' x 2' (0.61 m x 0.61 m) plot. With a storm of 3 in (7.62 cm) over 1 hour, the total kinetic energy produced by the

simulator was estimated to be 456 joules. Runoff and sediment were funneled into containers at the downslope end of the plot. Two rainfall simulation experiments were conducted at each of 37 sites, selected on the basis of soils, vegetation, slope gradient, and range condition by preliminary mapping and field inspection. Characteristics of the plot were recorded in the field and a soil sample was acquired for laboratory study, to facilitate later regression analyses with the sediment and runoff data.

Maps of slope gradient, vegetation density, and soil texture were digitized for use in a geographic information system established for the Middle Fork of the Fifteenmile Creek watershed. These variables were selected after regression analysis showed that they exerted the greatest control on sediment and water production in the rainfall simulator experiments.

Sixty-six morphometric variables describing the drainage basin, channel network, and relationship between the drainage basin and channel network, were measured for the South Fork, Middle Fork, and Main Fork subbasins of Fifteenmile Creek. The BLM provided storm-period sediment discharge data for the three subbasins.

Principal findings and significance:

The factors most important in determining both rainsplash-sheet erosion and runoff in the Middle Fork of Fifteenmile Creek watershed are slope gradient, vegetation density/litter density, and soil texture. These three variables account for 79.2 percent and 67 percent of the variation in gross erosion and runoff, respectively, in the regression analyses. The maps of slope gradient, vegetation density, and soil texture were combined in a geographic information system using the appropriate regression equation to produce maps of gross erosion and runoff for the Middle Fork watershed. Rates of erosion vary significantly within the watershed as a function of terrain type, with badlands accounting for a disproportionately high percentage of the upland sediment production. Rates of runoff displayed a similar geographic pattern, but not as pronounced as with sediment.

The differences in sediment production between the South Fork, Middle Fork, and Main Fork of Fifteenmile Creek watershed can be explained in a qualitative sense by several morphometric variables. However, the storm-period sediment discharge data provided by BLM for the subbasins provides only three dependent points to use in a regression analysis with morphometric variables, inadequate for any reliable statistical interpretation.

The computer assisted maps of gross erosion and runoff will be used by the BLM to concentrate their watershed improvement projects on those variables having the greatest influence on sediment production and on those areas of the basin which contribute disproportionately high to sediment production. The maps are also useful to investigators of the riparian zone sediment production who wish to place that contribution in perspective.

Publications and professional presentations:

PUBLICATIONS:

Dolan, L.S. and R.A. Marston (submitted): Computer assisted mapping of sediment production from an arid watershed. Journal of Soil and Water Conservation.

Marston, R.A. and L.S. Dolan (submitted). Estimates of upland erosion and runoff in an arid watershed in Wyoming. Final Project Report prepared for the Wyoming Water Research Center: Laramie, WY, approx. 200 pp.

Dolan, L.S. and R.A. Marston. 1988: Factors affecting rainsplash erosion and runoff in an arid watershed. Water and the West, Proceedings of a Symposium on Water Resources and Related Issues. American Society of Civil Engineers, Wyoming Section: Cheyenne, WY, pp. 137-142.

Marston, R.A. and L.S. Dolan. 1988: Rainsplash and runoff on a heavily grazed, badland watershed, Wyoming. Abstracts of Papers Presented at the 84th Annual Meeting, Association of American Geographers: Phoenix, AZ, p. 43.

PROFESSIONAL PRESENTATIONS:

Dolan, L.S. and R.A. Marston. 1988: Factors influencing rainsplash erosion and runoff in an arid watershed. Paper presented at the Symposium on Water Resources and Related Issues, American Society of Civil Engineers, Wyoming Section: Cheyenne, WY, 4-29-88.

Marston, R.A. and L.S. Dolan. 1988: Poster presented at the 84th Annual Meeting, Association of American Geographers: Phoenix, AZ, 4-7-88.

Marston, R.A. 1988: Use of a rainfall simulator to estimate sediment and water production from an arid watershed in Wyoming. Paper presented to the Interagency Soil Scientist Workshop, Soil Conservation Service: Casper, WY, 3-24-88.

M.A. thesis:

Dolan, L.S. 1988: Estimating upland sediment production using rainfall simulation. M.A. Thesis, Department of Geography and Recreation, University of Wyoming: Laramie, WY, 105 pp.

Ph.D. dissertations:

None

SYNOPSIS

Project Number: 07

Start: 6/1/87
End: 5/31/88

Title: Multiobjective Water Quality Management of Stream Environment

Principal Investigators: Y.K. Tung, L.E. Borgman, University of Wyoming, Laramie

COWRR: 05G

Congressional District: One

Descriptors: water quality management, model studies, stream pollution, multiobjective planning

Problem and research objectives:

Water quality management for stream environments involves waste load allocation; a process by which each waste discharger is allocated a share of the waste assimilative capacity of a receiving stream. Waste load allocation is the basis for NPDES permits and treatment requirements. This allocation process is a problem faced frequently by federal and state water quality regulatory agencies. The results of such a decision-making process have profound implications on environmental preservation and economic development of a region. Therefore, the use of effective methodologies for decision-making by any water quality regulatory agency is essential.

In addition to consideration of instream water quality standards, economic development of the region, equity of treatment among waste dischargers, decision-making in waste load allocation is further complicated by the presence of inherent randomness in the physical, biological, and chemical aspects of streams. Hence, the task of water quality management is multiobjective by nature. Realistic and effective management decisions can only be achieved by considering the tradeoffs among various objectives.

The main objective of this research was to develop a water quality management methodology using the framework of multiobjective decision-making. Specifically, waste load allocation in stochastic stream environments was examined. Furthermore, as a secondary objective of the research, the spatial and cross correlations of water quality parameters were taken into account in the multiobjective waste load allocation modeling.

Methodology:

The analysis of spatial and cross correlations of water quality parameters were made through unconditional simulation and variogram analysis developed in the field of geostatistics. This analysis enables one to assess the statistical properties of random elements in multiobjective stochastic waste load allocation models.

The stochastic nature of the waste load allocation exercise was considered through the framework of chance-constrained modeling. The developed multiobjective waste load allocation model included the following four objectives: (1) maximization of total waste load (equivalent to the minimization of treatment cost), (2) minimization of the largest difference in waste treatment, (3) maximization of the lowest allowable dissolved oxygen concentration, and (4) maximization of the lowest reliability of complying with water quality standards.

Principal findings and significance:

The presence of spatial and cross correlations among water quality parameters has a significant effect on the maximum amount of waste that can be discharged into a stream system. Effective decision making in the waste load allocation process has to explicitly consider the existence of such correlation. Furthermore, the multiobjective analysis revealed that tremendously useful information can be gained for effective decision-making in water quality management problems. The principal contribution of the research was to integrate the existence of uncertainty in water quality parameters into multiobjective water quality management problems.

Publications and professional presentations:

Two technical papers were prepared and submitted for possible publication in refereed journals.

"Stochastic Waste Load Allocation", by Y.K. Tung, W.E. Hathhorn, and L.E. Borgman. Submitted to the Journal of Environmental Engineering, ASCE.

"Multiobjective Stochastic Waste Load Allocation", by Y.K. Tung. Submitted to the Journal of Water Resources Planning and Management, ASCE.

M.S. thesis:

Stochastic Optimal Waste Load Allocation in a Stream Environment Under Uncertainty. 1987. W.E. Hatthorn. University of Wyoming, Laramie.

Ph.D. dissertations:

None

INFORMATION TRANSFER ACTIVITIES

DISSEMINATION OF RESEARCH RESULTS

'87 Wyoming Water Development and Streamside Zones Tour

A tour of some of Wyoming's water resources and streamside zones was organized to provide participants the opportunity to observe and discuss water and related resource issues of concern in the State. The caravan tour of the Cody, Wyoming area was conducted August 31 - September 1, 1987.

Sponsors for the tour included the Wyoming Water Research Center, University of Wyoming Agricultural Extension Service, Wyoming Game and Fish Department, U.S. Soil Conservation Service, Wyoming Association of Municipalities, Wyoming Water Development Commission, Bureau of Reclamation, Wyoming Department of Agriculture, Bureau of Land Management, Shoshone National Forest, and the Department of Environmental Quality.

Tour topics were: water storage, in-stream flow, riparian grazing, irrigation methods, irrigation return flows, channel erosion, siltation of reservoirs, fisheries habitat, municipal and industrial water, water supplies, state and federal water laws, and interstate water compacts.

Farmers, ranchers, land managers, water users, legislators, fishermen, and city planners benefitted from this tour. The tour was set up to provide a teaching and learning experience for the participants in an attempt to develop a more informed citizenry who can contribute to the future of Wyoming.

Governor's Economic Development Seminar and Field Tour

The WWRC conducted a public Wyoming Water Resources Symposium in 1985 and 1986 and an '87 Streamsides Zones and Water Development Tour. As WWRC was beginning plans for a water resources tour for 1988, Governor Sullivan requested the tour include an emphasis on potential economic development in the State. Thus, plans are now underway to conduct a Governor's Economic Development Seminar and Field Tour, August 24-26, 1988. The seminar and tour will be conducted in the Carbon County area. Discussions and tour stops will emphasize the importance of water resources in relation to the development of other available resources.

The Governor will issue special invitations to state leaders to attend the tour. The tour is being planned under the leadership of the WWRC in cooperation with the Governor's Office, Economic Development and Stabilization Board, State Engineer's Office, Water Development Commission, State Department of Agriculture, Wyoming Game and Fish, UW Cooperative Extension Service, U.S. Bureau of Reclamation and U.S. Bureau of Land Management.

Tour stops and discussions will include available and development plans of water, oil, gas, coal, timber, recreation, wildlife, transportation systems, communication systems and agricultural resources.

Water Resources and Water Law Seminar for Wyoming Legislators

The Wyoming Water Research Center and the Legislative Service Office, in cooperation with the Wyoming State Engineer, Attorney General, and Wyoming Water Development Commission, conducted a water resources information meeting for Wyoming legislators. The meeting was

held January 13, 1988 in Cheyenne. Twenty-six Wyoming legislators attended the one-day session. The seminar opened with a session on reviewing water terms and Wyoming's ground and surface water supplies. Water issues impacting Wyoming water use and development were discussed by the State Engineer. The State Attorney General lead a discussion on suitable timing to develop Wyoming's available water resources. The Administrator of the Wyoming Water Development Commission and the Chief of the Water Division of the Economic Development and Stabilization Board reviewed the water programs and projects that were going to be brought before the legislative session for action.

A comprehensive folder containing information presented during the seminar was distributed to each participant. Similar seminars have been held in previous years preceding the legislative sessions. To date, nearly 100 legislators have attended.

Wyoming Water Institute for Teachers

The Wyoming Water Research Center, in cooperation with the Wyoming Center for Teaching and Learning at the University of Wyoming, are sponsoring the Water Institute for Teachers scheduled for July 11-22 at the University of Wyoming.

The two-hour credit course will provide teachers with much information about and practical applications for Wyoming's water resources. Institute participants will be able to incorporate this information into existing curricula in such classes as history, science, chemistry and geography. Teachers will also be provided with many resources such as tapes, practical experiments and computer programs that illustrate scientific principles.

The course will be divided between classroom lessons and practical applications and field tours. UW faculty members and others will explain and demonstrate such things as water quality issues, water uses, resource management, watershed management and irrigation. A panel discussion will be held on water laws and policies with local, state and national lawmakers, including U.S. Senator Malcolm Wallop, State Senator Richard Larson, State Attorney General Joe Meyer, State Engineer Jeff Fassett and citizen Beryl Churchill.

Second Annual Frank J. Trelease Western Water Rights Symposium

The Second Annual Frank J. Trelease Western Water Rights Symposium honors a man whose name is synonymous with water law. This symposium is dedicated to Frank's memory and to achieving, through discussion and debate, sound water policies for our future. The symposium examined contemporary water law issues associated with western water problems in regard to the prior appropriation doctrine, quantity and quality issues associated with groundwater, wilderness designations, instream flows, and water transfers.

The symposium was sponsored by the University of Wyoming College of Law, the Wyoming Water Research Center and the Wyoming Centennial Project and was held in Jackson Hole, Wyoming, March 4-5, 1988.

Land and Water Law Review

The College of Law at the University of Wyoming produces a refereed law journal on a semiannual basis entitled "Land and Water Law Review." This journal is partially funded by the Wyoming Water Research Center through the USGS Section 104 Information Transfer allocation. Several articles each year on western water issues are published in this

journal. Titles and authors of three water articles published this past year are listed below.

1. Water Rights Transfers and Third Party Effects, George A. Gould, Land and Water Law Review, Vol. 23, 1988.

2. Water and Wilderness/Law and Politics, John Leshy, Land and Water Law Review, Vol. 23, 1988.

3. The Public's Role in the Acquisition and Enforcement of Instream Flows, Lori Potter, Land and Water Law Review, Vol. 23, 1988.

Acid Rain Workshop

The WWRC, in cooperation with the Wyoming Department of Environmental Quality, sponsored and coordinated an information dissemination workshop on atmospheric deposition research and monitoring on-going in Wyoming on February 26, 1988. Participation came from industry, academia, state and federal agencies, and private citizens. The Governor has requested that this effort be continued by the DEQ and WWRC in compliance with recommendations from the State's Acid Rain Task Force.

Water Resources Data System

The Water Resources Data System (WRDS) has provided water related data to Wyoming researchers for over a decade. The system, through the years, has developed into the most comprehensive single source of hydrologic and climatologic data available for the State of Wyoming. Data from more than 80 different collecting agencies are housed on the system and may be retrieved for listing or analysis. Output from such retrievals may be placed into a variety of media, including hardcopy printouts, floppy disks, magnetic tapes, and 35 mm color slides. The broad applicability of the system is attested to by the variety of its users. The system has provided information to many federal, state,

county and municipal agencies and private firms. Requests were processed for over 118 different users.

WRDS is responsive to state requests. Two examples of assistance during this past year were: (1) a request from the Wyoming Game and Fish Department to perform an analysis of daily streamflow records during a critical period for each water year by station, as defined by that agency; and (2) the manipulation and analysis of climatological records via custom programming as input to computer modeling efforts by the Wyoming Department of Environmental Quality - Solid Waste Management Program.

Wyoming Water Bibliography

The Wyoming Water Bibliography (WWB), a service project requested by the State, is the most comprehensive, multidisciplinary, computer-based bibliographic storage and retrieval system regarding Wyoming's water resources. Currently operational, the WWB contains approximately 12,500 citations which can be searched, free of charge, on a request basis. A User's Manual for the system is available and has been mailed to over 1,000 people in the State involved with water issues, including legislators, agency personnel, representatives of county and municipal governments, libraries, special interest groups and interested members of the private sector. Requests were processed for over 22 different users.

The Wyoming Water Research Center continues to work with the State Library in Cheyenne to provide search and retrieval on the Wyoming Water Bibliography for other state agencies in addition to updating the database itself with state documents.

Other Information Transfer Activities

The Wyoming Water Research Center uses several networks to inform the public and private sector of research activities in the State. UW 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.

1. During spring semester 1988, the Water Research Center sponsored a seminar series for the purpose of providing a forum for and increase discussion about water resources related studies or activities on the UW campus. "Water Talk" was held each Friday, and consisted of substantive presentations of proposed, ongoing or completed research activities. Attendance averaged 25-30 per week. Several state agency personnel attended. The series will continue next fall.

2. Two public water resources seminars were co-sponsored by the Wyoming Water Research Center and several state agency groups. The seminars were structured to permit open discussion between people interested in the management and development of Wyoming's water resources:

a. Water Resources Seminar, held at Northwest Community College, Powell, Wyoming, January 5-6, 1988.

b. Water Management Seminar, held at Eastern Wyoming Community College, Torrington, Wyoming, January 18, 1988.

Specific documents circulated among users in the state are:

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

4. WWRC Progress Reports. Distributed annually to advisory committees and to the Wyoming State Legislature.

5. Water Research Center Publications List.

6. Directory of Water Resources Individuals from State and Federal Agencies in Wyoming 1988. Prepared by the Wyoming Water Research Center, in cooperation with the State Water Forum.

Water Center faculty, professional staff, students and University faculty associated with Water Center projects were active in professional meetings and presentations. During this past year, the Water Center made special efforts with regard to activities oriented toward transferring information to potential users as well as making individuals and organizations aware of the WWRC and its activities and products. Thirty-five (35) presentations oriented toward WWRC and USGS priority activities were given, and professional and Center reports numbered twenty (20) toward these same activities.

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

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

University Service

- o Member, University of Wyoming Deans Council.
- o Serve on University committees.
- o 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
	Dept. of Environmental Quality Air, Land and 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 and Gas Conservation Commission
	Recreation Commission
	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
FY1987

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

- Production of Input-Output Model, county-by-county water use in Wyoming (Economic Development and Stabilization Board, Wyoming Water Development Commission and Wyoming Recreation Commission) - continued financial support

- 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)

- Flood Design Frequencies for Drainage Basins in Wyoming (Wyoming Highway Department)

- Snowy Range Watershed Laboratory - continued financial support

- 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)

- Livestock Stocking Rates/Fifteenmile Creek near Worland, 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 the Regional Climate Center in Lincoln, Nebraska (Farmers, Ranchers, Numerous State Agencies)

TABLE 2
(continued)

Service-to-State
FY1987

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

- Summary report of materials collected by the Governor's Acid Rain Coordinating Committee (Department of Environmental Quality, Governor's Office)

- 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)

- Water Expertise Directory (State Water Forum)

- Water Quality of Laramie's Water Supply (City of Laramie)

- 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, 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 FY87

Research accomplishments of the FY87 Federal Water Research Program were reviewed by the Director. The results of the projects sponsored with FY87 monies have been provided to the Center's advisory committees and presented at professional meetings.

- Federal Program FY88

The Director solicited proposals under the FY88 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 multidisciplinary 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.

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. A training session on the use of the system was given at the WWRC for interested University and state personnel.

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) of the U.S. Geological Survey, the Earth Science Data Directory (ESDD) of the U.S. Geological Survey, the Storage and Retrieval System (STORET) of the U.S. Environmental Protection Agency, and the NAWDEX System itself.

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

The WWRC has represented the University of Wyoming in a series of meetings exploring the potential for developing a coordinated GIS for Wyoming. The Vice-President for Research at UW has designated the WWRC as liaison between UW faculty and the State for GIS matters.

WWRC ADVISORY STRUCTURE

The organizational structure and operational procedures of 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. 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, research needs as they may have been perceived to change, 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

TABLE 3

WYOMING WATER RESEARCH CENTER

RESEARCH REVIEW AND PRIORITIES COMMITTEE

January 1988

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

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

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

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

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

UW President's Appointees:

Steven P. Gloss
(Executive Secretary)
Director
Wyoming Water Research Center
Vocational Annex Building
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 Department
Biological Sciences Bldg.
University of Wyoming
766-4207

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

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[1]Designated member of RRPC by Charter of WWRC, includes State Climatologist if position is filled.

TABLE 4

WYOMING WATER RESEARCH CENTER
RESEARCH REVIEW & PRIORITIES COMMITTEE

CITIZENS WATER ISSUES ADVISORY COUNCIL[1]

January 1988

Walter Yose, Jr.
P.O. Box 94
LaBarge, WY 82123
386-2322

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

Jim Noble
Box 80
Cora, WY 82925
367-4553

Tom Hill
Thayer School
801 S. 24th
Laramie, WY 82070
721-4450

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 Company
P.O. Box 720
Casper, WY 82602
577-6901

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

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[1]This advisory group will consist of not more than 20 members selected by the Governor and the University of Wyoming President, and should represent (a) Agriculture, (b) Recreation, (c) Municipalities, (d) National Forest Service, Bureau of Land Management, Bureau of Reclamation, or National Fish and Wildlife Service, (e) Consulting Engineers, (f) the State Legislature, (g) Industry, (h) Environmental Interests, (i) Private Citizens, (j) Legal Profession, (k) Political Action Groups, (such as the League of Women Voters), (l) Wyoming Higher Education System, and (m) State Agencies.

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.

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 1987 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	1				1
Civil	1				1
Environmental		1			1
Geology	1	1			2
Hydrology	1				1
Agronomy					
Biology		1			1
Ecology					
Fisheries, Wildlife and Forestry (Zoology)	2	2	1		5
Computer Science					
Economics					
Geography		1			1
Law					
Resources Planning					
Other - specify					
Accounting	1				1
Statistics		1			1
TOTAL	7	7	1		15