

QH541  
C7  
no.1

An Inventory of  
**ENVIRONMENTAL RESOURCES**  
**RESEARCH**  
in Progress

COLORADO STATE UNIVERSITY

January 1971

ENVIRONMENTAL RESOURCES



CENTER

Colorado State University  
Fort Collins, Colorado

Information Series No. 1

## FOREWORD

This special report has been assembled by the Environmental Resources Center staff from annual progress reports submitted by colleges to the Vice President for Research. It has been compiled to summarize work in progress on subjects closely related to environmental quality.

Research projects selected for this summary represent by no means all of the research in progress at Colorado State University. Neither do they represent all research which might be classified in natural resources. To keep it of manageable size, the focus has been placed upon environmental concerns and closely related natural resources problems. In general, research inventory, development, marketing, and processing of natural resources has not been included.

Although the Environmental Resources Center is providing this report as a service to others, it should be made clear that the Center itself performs no research. All research at Colorado State University is conducted under the administrative direction of the Dean of a College and the Chairman of a Department. The Center along with the Experiment Station serves the faculty as a point of coordination for interdisciplinary research and serves those outside the University as a point of contact for inquiries.

A subject classification has been made arbitrarily by the editor as a convenience to those who may use this report. Many projects could be placed in several categories.

Those projects which are supported in part by federal funds allocated through the Office of Water Resources Research, U.S. Department of Interior under P.L. 88-379, are identified by project numbers following the title. Other projects having outside sponsorship are identified by naming the sponsor following the abstract. Those not otherwise identified are sponsored by the Experiment Station.



Director, Environmental  
Resources Center

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## WATER QUALITY



### Nitrogen in the Environment

#### OBJECTIVES

To identify and quantify the parameters of soil systems for prediction of nitrogen behavior and to develop technological and managerial practices to control the mobility of nitrogen in the soil, thereby providing maximum supplies of nutrients for plant growth and minimum potential for pollution of ground and surface waters.

#### APPROACH

Laboratory studies using incubation and soil column techniques with varying rates of animal manure and nitrate, and with various soil moisture conditions, will be made. Using similar treatments, a greenhouse study will be initiated wherein plants will be introduced into the system to study their influence on the transformation. Eventually, if supplementary funds can be obtained, a field experiment will be started wherein each plot will be made into a lysimeter. All percolating waters will be monitored by measuring the amount of effluent and taking samples for determining possible pollutants.

Principal Investigator: *B. R. Sabey*

Discipline Involved: *Agronomy*

Beginning Date: *7-1-70* Completion Date: *6-30-75*



### Data Acquisition Systems in Water Quality Management

#### OBJECTIVES

To analyze the capabilities of three different water quality data acquisition systems--sampling/wet chemistry, electronic sensing probes, aerial surveillance--and to develop a procedure for designing a state water quality monitoring system which is most responsive to program objectives, utilizing the best combination of the three data acquisition techniques.

#### APPROACH

The approach will be to determine the general objectives of the state water quality program, to

delineate the type and quantity of information needed to accomplish these objectives, to survey the state-of-the-art of each technique, to develop a procedure for designing a state water quality monitoring program, and to apply the procedure using the State of Colorado as a model.

Principal Investigator: *R. C. Ward*

Discipline Involved: *Agricultural Engineering*

Beginning Date: *7-1-70* Completion Date: *12-31-71*

Sponsor: *F.W.Q.A.*



### Soil Salinity and Water Quality

#### OBJECTIVES

To determine more precise criteria for evaluating and managing irrigation waters of varying quality, methods for improving water percolation and uniformity in slowing permeable soils, dissolution rates of native and added gypsum, and rapid and accurate methods for routine salinity analyses.

#### APPROACH

Greenhouse and field studies will be conducted to characterize  $\text{SO}_4\text{-HCO}_3$  type irrigation waters. Field subsoil tillage and other treatments will be investigated to improve water percolation. Laboratory studies of gypsum solubilities in soils will be made. The adaptability and accuracy of specific ion electrodes will be investigated.

Principal Investigators: *William T. Franklin, Robert S. Whitney, C. W. Robinson*

Discipline Involved: *Agronomy*

Beginning Date: *3-31-69* Completion Date: *1-30-73*



### Management of Salt Load in Irrigation Agriculture

#### OBJECTIVES

To develop alternative methods of managing the salt load in irrigated agriculture to optimize beneficial use of water.

## APPROACH

A digital computer model (two dimensional) will be modified to incorporate water quality parameters. Field plots will be utilized to verify the models and study alternatives in drainage water management.

Principal Investigators: *Norman A. Evans,*  
*Daniel K. Sunada*

Discipline Involved: *Agricultural Engineering*

Beginning Date: *7-1-69* Completion Date: *6-30-74*



Water Quality Management Decisions  
in Colorado (OWRR A-010-COLO)

## OBJECTIVES

The purpose of this work is to study the operation of the Colorado Water Quality program in order to develop a constructive critique which will assist in future program development. To accomplish this, the following objectives will be pursued:

1. Evaluate Colorado's present monitoring system for surveillance of stream standards with respect to both present and potential sources of pollution.
2. Evaluate the capability of present institutional programs to anticipate potential pollution problems and for providing information necessary in decision-making regarding water quality management.
3. Evaluate present and projected institutional processes for pollution enforcement in Colorado, along with alternative methods for attaining conformance with stream standards.

## APPRGACH

Reliance will be placed upon case studies involving decisions by the Colorado Water Pollution Control Commission, together with policy statements and procedures established by that agency. Interviews will be conducted with parties involved in the selected cases to obtain attitudes with a variety of sources throughout the State, to assist in evaluating the present institutional processes for making adequate decisions, and to assist in evaluating the effectiveness of present enforcement techniques.

Principal Investigators: *Gaylord V. Skogerboe, R. C. Ward*

Discipline Involved: *Agricultural Engineering*

Beginning Date: *7-69*

Completion Date: *6-72*



### **Effects of Sodium Nitrate and Water Contaminants on Turkey Performance**

#### **OBJECTIVES**

To establish the cause of delayed growth response after bronze turkeys receive drinking water containing sodium nitrate for the first four weeks of life.

#### **APPROACH**

The effect of the sodium nitrate treatment will be sought by concentrated examination of turkey carcasses. Since we have noticed a trend towards reduced testes size, gonadotrophin elaboration and metabolism will be studied in turkeys that have or have not received the sodium nitrate treatment. Efficiency of meat production will be determined, and meat characteristics will be examined.

For the other phase of the experimentation, selected Colorado water samples will be compared to distilled water for growing turkey performance. The effects of biological contaminants in turkey drinking water and ways to reduce ill effects of such contamination will be studied.

Principal Investigator: *E. W. Kienholz*

Discipline Involved: *Avian Science*

Beginning Date: *7-1-68*

Completion Date: *6-30-74*



### **Grand Valley Salinity Control**

#### **OBJECTIVES**

1. To demonstrate that the mineral quality of the Colorado River can be improved by lining irrigation canals and other water conveyance channels.
2. To evaluate the effectiveness and general applicability of this method of salinity control.

## APPROACH

In three selected study areas, irrigation canals and other water conveyance channels will be lined to control the major source of recharge to the near-surface aquifers; thereby minimizing the quantity of flow through mineral yielding geological formations and reducing the gradient which forces saline water into the Colorado River. Detailed field observations and measurements will be made to evaluate the effectiveness of lining in preventing seepage and the reduction in salt load return to the Colorado River.

Principal Investigator: *Gaylord V. Skogerboe*

Discipline Involved: *Agricultural Engineering*

Beginning Date: *7-1-68* Completion Date: *6-30-72*

Sponsor: *Experiment Station, F.W.Q.A.*



A System for Geologic Evaluation of  
Pollution Potential at Mountain Dwelling  
Sites (OWRR B-023-COLO)

## OBJECTIVES

The research is to develop a hydrogeologic classification system for mountainous terrain. The classification system is to be designed for use in evaluating pollution potential at dwelling sites in the mountains.

Streams and wells in the mountains are susceptible to contamination because sewage disposal systems are usually privately owned and may be poorly situated or constructed. In addition, contaminated surface water can usually percolate directly into the ground via exposures of fractured or jointed rock. Also, direction and rate of ground water motion in a fractured medium are difficult to determine.

## APPROACH

The procedure needed for this research is to collect quantitative measures of topographic, geologic, and hydrologic variables. These data are to be used in a discriminant function analysis. The data will be in two groups: group I will contain information from sites where contamination has been documented and a source of pollution can be identified; group II will contain information from sites where no contamination can be detected, but where a pollution source is present.



Principal Investigators: *J. P. Waltz, S. M. Morrison*

Disciplines Involved: *Geology, Microbiology*

Beginning Date: *7-68*

Completion Date: *6-71*



**Sedimentation and Contaminant Criteria for  
Water Resources Planning and Management  
(OWRR B-014-COLO)**

## **OBJECTIVES**

To study the effect of vegetation on flow rate, sediment yield, and dispersion of pollutants on watersheds.

## **APPROACH**

Laboratory models of alluvial channels will be used.

Principal Investigators: *H. W. Shen, D. B. Simons*

Discipline Involved: *Engineering*

Beginning Date: *7-67*

Completion Date: *6-31-71*



**Evaluation of Physical, Chemical,  
and Biological Quality of Reservoirs**

## **OBJECTIVES**

To evaluate the effect of impoundment on water quality.

## **APPROACH**

Data collected from the reservoir were analyzed by constituents and related to water quantity in the reservoir.

Principal Investigator: *S. Karaki*

Discipline Involved: *Civil Engineering*

Beginning Date: *6-67*

Completion Date: *Open*

Sponsor: *U.S.D.I. - Bureau of Reclamation*



## Reaeration in Open-channel Flow

### OBJECTIVES

Streams and rivers require a continuous supply of dissolved oxygen to replace the oxygen consumed in the biodegradation of organic wastes. The principal process by which the oxygen is replaced is absorption from the atmosphere, and the purpose of this project is to obtain a better understanding of the reaeration process so that reaeration rates can be predicted from measurable flow and fluid properties.

### APPROACH

Water circulating in a laboratory flume is deoxygenated using sodium sulfite and a cobalt chloride catalyst. The rate of reaeration of the water is measured under a variety of hydraulic conditions and width-depth ratios.

Principal Investigator: *Ron Rathbun*

Discipline Involved: *Civil Engineering*

Beginning Date: *7-1-69* Completion Date: *6-30-70*

Sponsor: *U. S. Geological Survey*



## Improvement in BOD Tests (Biomedical Sciences Support Grant for 1969-1970)

### OBJECTIVES

The objective of the research was to investigate the rate of reaction of reagents such as ozone, peroxide, and superoxide with sewage or synthetic sewage. The purpose was to test the feasibility of replacing the cumbersome and unreliable BOD test with a more rapid oxidation employing another form of oxygen.

### APPROACH

Ozone and superoxide were generated electrochemically and their concentrations in the reaction mixture monitored electrochemically as a function of time.

Principal Investigator: *Janet Osteryoung*

Discipline Involved: *Civil Engineering*

Beginning Date: *6-1-69* Completion Date: *5-31-70*

Sponsor: *National Institutes of Health*

## ECOLOGICAL IMPACTS



### Vegetative Stabilization of Mine Tailings, Wastes, and Spoils

#### OBJECTIVES

1. To identify problems associated with establishing vegetation on mine tailings, wastes, and spoils.
2. To determine treatments, techniques, and species required to establish and maintain vegetation on tailings, wastes, and spoils.
3. To classify tailings, wastes, and spoils by chemical and physical composition, climate, and topographic features in relation to requirements for and feasibility of vegetative stabilization.

#### APPROACH

Treatments, techniques, and species for revegetation will be determined by a combination of laboratory, greenhouse, and field work. Physical and chemical properties significant to plant growth on the tailings, wastes, and spoils will be determined. Greenhouse studies will be used to investigate nutrient deficiencies and toxicities, and for exploratory work on species selection. Field experiments will be used for species selection, establishment techniques, nutrient and toxicity problems, and for determination of maintenance requirements, longevity, and feasibility.

Principal Investigator: *William A. Berg*

Discipline Involved: *Agronomy*

Beginning Date: *7-1-68*    Completion Date: *6-30-73*

Sponsor: *Mining Industry*



### Plants to Increase Highway Safety and Beauty and to Decrease Maintenance Cost and Prevent Erosion

#### OBJECTIVES

1. To determine the plant species, both woody and herbaceous, which will adequately cover the land adjacent to the paved areas so that erosion may be controlled, vehicle impact impeded, maintenance costs decreased, and overall scenic value and attractiveness enhanced.

2. To determine the most feasible and economic methods of propagation and nursery culture to produce selected plants in quantity to transplantable size.
3. To determine the feasibility of mechanical removal of native plants followed by artificial controls of temperature, light, and moisture in order to stimulate root regeneration and rapid conditioning for transplanting.

## APPROACH

Consult reports of investigations and observations on highway plants in other states; select certain species for observational planting in various site and climatic areas in Colorado; correlate growth response and adaptability of these species to various ecological factors; and investigate the physiological and economic factors relating to extended propagation, nursery growing, transplanting, mulching, and general aftercare required for these plant species.

Principal Investigator: *W. D. Holley*

Discipline Involved: *Horticulture*

Beginning Date: *7-1-69*      Completion Date: *7-1-72*



Environmental Improvement Through  
Biological Control and Pest Management

## OBJECTIVES

1. Development of principles of insect pest management for regional environmental improvement.
2. Multi-scale augmentation of biological control agents through environmental manipulation.
3. Recognition and experimental interchange of entomophagous biotypes for improved biological control.

## APPROACH

The existence of sex pheromones in several species of *Chrysopa* will be determined and their use evaluated in concentrating predators in alfalfa fields. Artificial food sprays will be applied in alfalfa fields and counts made on number of predators attracted to and feeding on these foods. *Bathyplectes* will be collected from various parts of Colorado and observed in the laboratory for signs of new biotypes. Any found will be reared and released in new areas, and observations will be made on their establishment.

Principal Investigator: *Robert G. Simpson*

Discipline Involved: *Entomology*

Beginning Date: *7-1-69* Completion Date: *6-30-74*



Chemical and Biological Control  
of Alfalfa Insects

## OBJECTIVES

To evaluate effectiveness of new insecticides for control of alfalfa pests. Investigate use of predators and parasites for alfalfa weevil control selection and evaluation of alfalfa varieties for resistance to spotted alfalfa aphid and pea aphid.

## APPROACH

Twenty-five new insecticides will be studied at Fort Collins and at Rocky Ford on infested alfalfa and the materials evaluated for effect on pest and beneficial insects. Parasites of the alfalfa weevil will be released in infested fields and checked over the next three years. Alfalfa clones will be evaluated in the field for resistance to spotted alfalfa aphid and pea aphid.

Principal Investigators: *Robert G. Simpson,*  
*Frank Schweissing*

Discipline Involved: *Entomology*

Beginning Date: *2-1-70* Completion Date: *2-1-73*



Biology and Influence of Rodents  
and Rabbits on Rangelands

## OBJECTIVES

To investigate distribution, population density, and change in density in range rodents and rabbits. To determine the diets of rodents and rabbits and the effects of forage removal by these animals. To study the relationship of rodents and rabbits to soil, watershed, and land management manipulations. To investigate techniques for control of vertebrates that damage rangeland. To conduct research on the life history, morphology, behavior, and physiology of rodents and rabbits important to rangelands.

## APPROACH

An advisory committee representing Colorado State University administrators, the Rocky Mountain Forest and Range Experiment Station, and the Fish and Wildlife Service defines priorities of research, cooperation, and prepares annual work plans. Research includes food habits study through micro-techniques using animals and available vegetation. Surface movements and population densities are measured with electric fences and other census techniques in natural conditions and where influenced by land management practices. Life history studies on morphology, physiology, and behavior are made both in laboratory and in the field with artificial populations or trap and release and observational methods. The total environment is evaluated to determine causes of presence or absence of rodents or rabbits in various sites and impacts of these animals on the site. Control methods involving poisons, methods of baiting and other means are investigated in feeding trials and field tests. Knowledge of rodent-rabbit-land interactions is then applied to problems of land management.

Principal Investigators: *R. M. Hansen, T. A. Vaughan*

Discipline Involved: *Range Science*

Beginning Date: *7-1-66* Completion Date: *6-30-71*



The Control of Pome Fruit Insects  
Through Integrated Approaches

## OBJECTIVES

To develop mass rearing methods for codling moth. To devise means of determining codling moth populations. To determine methods of inducing sterility in codling moth. To improve and refine cultural control methods and evaluate value of beneficial insects and chemicals in codling moth control.

## APPROACH

Codling moth larvae will be reared on apples and on various artificial media. Attractant traps and marked sterile adults released and recaptured will be used to estimate insect populations. Influence of orchard cover crops on insect populations will be determined. Chemosterilant and irradiation effect on moth fertility will be studied. Various insecticides

and predacious and parasitic insects will be studied in relation to insect control.

Principal Investigator: *John A. Quist*

Discipline Involved: *Entomology*

Beginning Date: *7-1-68*      Completion Date: *7-1-71*



### **Integrated Control of Stone Fruit Insect Problems**

#### **OBJECTIVES**

To develop means of mass rearing Oriental fruit moth. To determine methods for estimating populations of stone fruit pests. To develop methods of inducing sterility in stone fruit pests. To determine effects of cultural practices on populations of stone fruit pests. To evaluate effectiveness of beneficial insects and chemicals as controls for stone fruit pests.

#### **APPROACH**

Oriental fruit moth larvae will be reared on apples and on various artificial diets. Various means will be used for estimating pest populations (attractive traps, capture and release, etc.). Chemosterilants and eradication will be used to induce sterility in Oriental fruit moth. The influence of various cultural practices on pest populations will be determined. Effect of beneficial insects and various insecticides on stone fruit pests will be noted.

Principal Investigator: *John A. Quist*

Discipline Involved: *Entomology*

Beginning Date: *7-1-68*      Completion Date: *7-1-71*



### **Response of Plants and Plant Communities to Sustained Use of Herbicides**

#### **OBJECTIVES**

To determine effects of repetitive application or polluttional levels of herbicides on plant communities.

1. To determine effects of repeated applications of pre-emergence and post-emergence herbicides on bluegrass quality and production.

2. To study environmental factors affecting toxicity and selectivity of pre-emergence soil herbicides.
3. To determine the influence of soil temperature moisture, microflora, and organic matter on the disappearance of pyrazon, dicamba, and picloram.
4. To determine the direct and interacting effects of picloram and dicamba on the two soil plant pathogens- *Fusarium* sp. and *Rhizoctonia* sp.

Principal Investigator: *Jess Fults*

Discipline Involved: *Botany and Plant Pathology*

Beginning Date: *7-1-69* Completion Date: *6-30-74*



## Pesticide Mobility and Degradation in Soil-Water Systems

### OBJECTIVES

To identify the principal degradation products and to determine the mechanisms and kinetics of pesticide transformations in soil-water systems.

### APPROACH

Pesticides will be incubated with soils of varying chemical, physical, and mineralogical composition. Studies will be made of the influence of temperature, light, aeration, added organic matter, and moisture on pesticide decomposition in these soils. Degradation will also be followed in soil-water suspensions and in columns of soils perfused with pesticide solution. Efforts will be made to determine the kinetics of herbicide decomposition and to identify and characterize major degradation products as well as to isolate the microorganisms responsible for the degradation process.

Initial emphasis will be placed on studying the degradation of three herbicides: 2,4-dichlorophenoxyacetic acid (2,4-D); 2,4,5-trichlorophenoxyacetic acid (2,4,5-T); and picloram (Tordon).

Principal Investigator: *K. G. Doxtader*

Discipline Involved: *Agronomy*

Beginning Date: *7-1-69* Completion Date: *6-30-74*





## Biology and Control of Arthropod Pests of Landscape Plants in Colorado

### OBJECTIVES

To determine biology and control of *Thecodiplosis cockerelli* on pinyon pine in Colorado.

### APPROACH

Life history will be studied in the laboratory and in the field. Its distribution in Colorado will be determined. Several chemicals will be tested against the pest. Observations will be made on naturally occurring predators and parasites.

Principal Investigator: *J. Wayne Brewer*

Discipline Involved: *Entomology*

Beginning Date: *4-3-69*      Completion Date: *4-3-72*



## Induced Photolysis of Organic Halides-- Pathways for Photodecomposition of DDT

### OBJECTIVES

The feasibility of inducing the photochemical decomposition of organic halides will be investigated. The induced photochemical decomposition of DDT will receive special attention.

### APPROACH

Photolyses at wavelengths greater than 3000 Å will be undertaken with a variety of representative donors in a brief screening process to discover what sort of structural characteristics are necessary for induced decomposition. A more intensive study of those donors which are most effective will involve isolation and characterization of the photoproducts and elucidation of the reaction mechanism.

The products and pathways of induced DDT photolysis will also be investigated.

Principal Investigator: *Larry L. Miller*

Discipline Involved: *Chemistry*

Beginning Date: *7-1-69*      Completion Date: *6-30-72*



## **Residues of Selected Pesticides--Their Nature, Distribution, and Persistence in Plants, Animals, and the Physical Environment**

### **OBJECTIVES**

The metabolism of pesticide residues by plants and microorganisms as factors in modifying residue levels in food chains and in the environment. The effects of soil amendments such as sewage sludge and cattle manure on pesticide metabolism in Colorado soils will be studied.

### **APPROACH**

Soil with and without soil amendments will be uniformly treated with 10 ppm of a chlorinated hydrocarbon insecticide such as DDT and aldrin. At intervals the soil will be analyzed for residues and metabolites using standard chemical methods including gas chromatography (GLC) to determine the rate of metabolism. If rapid degradation occurs, attempts will be made to isolate and identify the responsible microorganism(s). Analytical methodology will be developed for materials which are non-pesticidal and known to interfere with GLC, such as the chlorinated naphthalenes.

Principal Investigators: *Richard E. Johnsen, R. I. Starr*

Discipline Involved: *Entomology*

Beginning Date: *7-1-68* Completion Date: *6-30-73*



## **Insecticide Decontamination of Colorado Soils by Utilization of Animal Wastes**

### **OBJECTIVES**

To examine animal wastes as energy for and source of microorganisms for biodegradation of chlorinated hydrocarbon insecticides in soil.

### **APPROACH**

Chlorinated hydrocarbon insecticides will be added to insecticide-free soil in Erlenmeyer flasks in measured amounts. To these flasks will be added samples of manure and sewage sludge, and the flasks will be stored for various periods of time at the end

of which they will be analyzed for insecticide content. From samples found low in insecticide, microorganisms will be isolated and multiplied in both and insecticides added, the broth incubated for 96 hours, and then analyzed for insecticide content.

Principal Investigator: *Richard E. Johnsen*

Discipline Involved: *Entomology*

Beginning Date: *7-1-69* Completion Date: *6-30-72*



Applied Ecological Study of Spring Creek,  
Fort Collins, Colorado

### OBJECTIVES

1. Study body of water adjacent to different types of land use areas.
2. Information concerning the effect of different land use on natural water.
3. Information for better advise on the application of ecological rules to land use planning.

### APPROACH

1. Oxygen and temperature profile of stream recorded simultaneously from the source to the mouth at different times of the year.
2. A study of pollution indicators such as tubificid worms will be made for some indication of the biological condition of the stream.
3. The areas drained by the stream will be mapped and classified according to use.
4. A study of the types and amount of invertebrates in different areas of the stream.
5. Record of the types and extent of solid wastes dumped into the stream in different areas.

Principal Investigators: *Charles G. Wilber,*  
*David Pettus, William Marquardt*

Discipline Involved: *Zoology*

Beginning Date: *7-1-70* Completion Date: *6-30-73*



Water Resources Hydraulics

### OBJECTIVES

Improved erosion and sedimentation theories including transport, degradation, and aggradation phenomena. The inclusion of concepts of turbulence,

diffusion, and probability theory will improve our working knowledge. Study in greater detail the mechanics of flow in both alluvial and rigid boundary channels to increase efficiency of water distribution, delivery, and application. As a long-range goal we must, with this broader understanding of river and related water resources development, consider the effects of water resources development on the river and its tributary system.

## APPROACH

Flumes will be used to study the processes of degradation and aggradation resulting from construction of dams and diversions works; also, the geometry of alternate bars in crossings, their response to changing flow conditions, and the variables affecting them. The measurement of turbulence in open channels will be further developed and related to sediment transport using a hot film device. Work will be initiated to show the absolute necessity of developing river basins in an integrated and coordinated manner. This will involve initially the utilization of basic theories developed and field data from eroding river systems.

Principal Investigators: *D. B. Simons, J. Gessler, M. M. Skinner, S. Karaki*

Discipline Involved: *Civil Engineering*

Beginning Date: *8-19-68* Completion Date: *6-30-73*



Selection of Test Variable for Minimal Detection of Basin Response to Natural or Induced Changes (OWRR A-011-COL)

## OBJECTIVES

The objectives of the study are to answer the following two questions:

1. Given a region consisting of  $N$  basin in which changes are suspected, and given that economic and financial constraints will limit to  $n$  the number of basins where measurements can be obtained, which  $n$  basins should be selected?
2. Furthermore, how should the measurements in individual basins be combined?

## APPROACH

The answer to the two objectives is obtained by minimizing the function  $F$  which contains the hydrologic quantities of interest and their variances and

covariances. The minimum value of F will be determined by a steepest decent technique, will be repeated for all possible combinations of n basins, and will find the absolute minimum.

Principal Investigator: *H. J. Morel-Seytoux*

Discipline Involved: *Civil Engineering*

Beginning Date: *7-69*

Completion Date: *6-71*



### Golden Eagle Ecology Study

#### OBJECTIVES

1. To determine influence of golden eagles on sheep and goat mortality.
2. To determine relationship of range conditions to eagle-livestock interactions.
3. To determine golden eagle population trends.
4. To determine which historical situations influenced the present condition of conflicts between golden eagles and livestock.

#### APPROACH

Objectives achieved by field observations of golden eagles in livestock inhabited areas, range surveys, routine and regular censuses, and diligent search of local and state historical records.

Principal Investigator: *F. Glover*

Discipline Involved: *Cooperative Wildlife Unit*

Beginning Date: *1-1-66*

Completion Date: *Open*

Sponsor: *National Audubon Society*



### Observations of Variations of Glaciers

#### OBJECTIVES

To continue the surveys started in 1926 by Dr. W. O. Field, American Geographic Society, in which the advances and retreats of the glaciers in Glacier Bay are recorded.

#### APPROACH

Using the National Park Service boat as a base, visits were made to established camera points from

which photographs were taken of the glacier fronts. In the cases where unusual changes had taken place since the 1968 survey, the wild theodolite provided by the American Geographic Society was used to determine the amount of change.

Principal Investigator: *David Harris*

Discipline Involved: *Geology*

Beginning Date: *7-30-69* Completion Date: *Open*

Sponsor: *U.S.D.I. - National Park Service*



### Experimental Study of Drainage Basin Evolution

#### OBJECTIVES

To document the erosional development of a model drainage system and to relate changes in the hydrologic character of the system (runoff, sediment yield, flood peaks) to the morphology of the system.

#### APPROACH

A 30 feet by 50 feet container (Drainage Evolution Research Facility) has been constructed and 400 cubic yards of a mixture of sand, silt, and clay placed in the container. Simulated precipitation can be applied at intensities ranging from 0.5 to 2.0 inches per hour. Precise mapping and photography will document the landform changes. Instruments have been installed to record precipitation, runoff, hydrographs, and sediment samples will be collected for analysis.

Principal Investigator: *Stanley Schumm*

Discipline Involved: *Geology*

Beginning Date: *1-1-70* Completion Date: *12-31-70*

Sponsor: *U. S. Army Research Office*



### Model Study of River Meanders

#### OBJECTIVES

The primary objective is to generate a meandering channel in a flume by changing sediment load and discharge characteristics. Based on early results, it was decided that an investigation of the influence of slope on river morphology would also be productive.

## APPROACH

The 24 feet wide by 100 feet long flume at the Engineering Research Center is used. The slope of the surface on which the model river was established is changed as is the quantity of sand introduced into the channel. Fine sediment is introduced to determine its effect on channel morphology.

Principal Investigator: *Stanley Schumm*

Discipline Involved: *Geology*

Beginning Date: *9-15-68* Completion Date: *6-15-71*

Sponsor: *National Science Foundation*



Radiation Transfer Through the Atmosphere

## OBJECTIVES

To investigate the role of semi-transparent (water drop clouds) layers on the transfer of visible and infrared radiation through the atmosphere.

## APPROACH

Simultaneous profiles of atmospheric aerosols, visible and infrared radiation temperatures, and water vapor collected on a companion project were used to test a radiation transfer model incorporating a solid and liquid particulate component.

Principal Investigator: *W. E. Marlatt*

Discipline Involved: *Atmospheric Science*

Beginning Date: *9-1-66* Completion Date: *8-31-71*

Sponsor: *1916 NASA Supporting Grant*



Pesticide Levels in Mule Deer

## OBJECTIVES

To determine whether the concentrations of pesticides found in Rocky Mountain mule deer, utilizing orchards and their environments near Paonia, Colorado, fluctuate between three stress periods.

To determine whether there is an ecological correlation between the concentrations of pesticides found in the mule deer and those found in the environment of the mule deer.

## APPROACH

Collect tissue samples from living deer through biopsy and dead deer through autopsy. Collect leaves of browse plants. Analyze both animal and vegetation samples for pesticides by gas chromatography. Analyze data by a missing data analysis of variance procedure.

Principal Investigator: *F. Glover*

Discipline Involved: *Cooperative Wildlife Unit*

Beginning Date: *1-1-67* Completion Date: *6-30-70*

Sponsor: *U.S.D.I. - Bureau of Sport Fisheries*



### **Influence of Turbidity on Aquatic Life of Streams**

## OBJECTIVES

1. To establish standard limits on the weight of solids suspended in water.
2. To establish which of the available turbidimeters gave the most accurate and reproducible readings.

## APPROACH

A Jackson Candle, Hellige, and Hach Model 2100 turbidimeter was used in two statistical designs to determine the best method of turbidity measurement. Seven materials were used in testing the turbidimeters: formazine, kaolin, silica, bentonite, fine carbon, sawdust, and a soil sample from Soap Creek.

Principal Investigator: *H. Everhart*

Discipline Involved: *Fisheries*

Beginning Date: *5-1-68* Completion Date: *5-31-70*

Sponsor: *U.S.D.I. - Bureau of Reclamation*



### **Chemical Variations in Aquatic Environments**

## OBJECTIVES

1. To evaluate oil shale country for possible effects of mining, and to investigate toxicity of some of the likely pollutants to rainbow trout.
2. To evaluate the effects of aluminum on eggs, fry, and fingerling rainbow trout.



3. To evaluate the effects of lead on eggs, fry, and fingerling rainbow trout.

#### APPROACH

A biological inventory of Piceance Creek and some work on White River were completed for "before" information.

Bioassays to determine the effects of aluminum at concentrations of 5.2 ppm, 0.52 ppm, and 0.052 ppm at pHs of 7.0, 8.0, and 9.0 were completed. Similar bioassays will be conducted for the eggs and fry. The toxicity studies of lead are in progress.

Principal Investigator: *H. Everhart*

Discipline Involved: *Fisheries*

Beginning Date: *5-1-70* Completion Date: *4-30-71*

Sponsor: *U. S. Department of Interior*



#### Movement and Translocation of Systemic Insecticides in Coniferous Forest Trees

#### OBJECTIVES

To determine potential of cacodylic acid as systemic insecticide for control of Engelmann spruce beetle followed by search and development of ideal chemical which may be translocated to phloem with characteristics: absorbed through foliage, low in toxicity to beneficial forest fauna, non-phytotoxic, and highly toxic to bark beetles.

#### APPROACH

Eight spruce trees will be injected with cacodylic acid in varying dosages and methods. Samples of phloem and xylem will be removed from three standing trees at 5, 10, and 20 foot heights. Half of each will be fed to beetles for bioassay and half will be used for chemical analysis. Similar tests will be made on three untreated trees. Samples will be taken after 1, 2, 4, and 8 days. Eight days after treatment, five treated and five untreated trees will be felled, two 20-inch bolts will be cut from each tree at 5, 10, and 20 foot intervals, and each bolt will be individually caged and charged with 16 beetles per square foot of bark. Brood and gallery development will be observed and become naturally infected and then will be observed and measured after 30 days.

Principal Investigators: *Noel D. Wygant, R. E. Johnsen*

Discipline Involved: *Forest and Wood Sciences*

Beginning Date: *9-68* Completion Date: *6-30-71*

## AIR QUALITY



### Awareness of Air Pollution and Its Causes

#### OBJECTIVES

During 1970-71 a second phase of work on public awareness of air pollution in Colorado will be initiated. Phase one of this project was concerned with a general attitude survey of several Colorado communities designed to measure public attitudes toward the problem of air pollution. In phase two, attitudes toward air pollution will be correlated with perceptions of air quality. Both field and laboratory methodology will be employed.

#### APPROACH

Repeated independent samples of households in north Denver known to be among the heaviest air pollution areas in Colorado will be surveyed on days varying in pollution level. Respondants will be asked their perceptions of the air quality on that day and attitudes about air pollution in general. The surveys will extend over a year. Concurrently with the field sample, a laboratory study will be performed to assess judgments of air quality from a series of photographs. The methodology of signal detection theory will be employed in the laboratory work.

Principal Investigator: *Ross Loomis*

Discipline Involved: *Psychology*

Beginning Date: *7-1-70* Completion Date: *6-30-71*



### Reduction of Nitric Oxide by Graphite

#### OBJECTIVES

The objective of the project is to experimentally determine the rate and extent of conversion of nitric oxide to nitrogen and carbon dioxide by the solid-gas reaction with graphite. Interest in this reaction stems from its possible usefulness for vehicular emission control.

## APPROACH

Experimental.

Principal Investigator: *Harry Edwards*

Discipline Involved: *Mechanical Engineering*

Beginning Date: *5-1-70* Completion Date: *4-30-71*

Sponsor: *Environmental Health Service*



Technique--Estimating  
Atmospheric Dispersion  
Research and Development

## OBJECTIVES

To utilize the wind tunnel as a tool to model the atmospheric planetary boundary layer over mountainous terrain and the transport-dispersion of a passive tracer material simulating the silver iodide seeding material to determine:

1. Under given storm conditions, will artificial freezing nuclei reach the target area?
2. How much of the target volume will be covered (i.e., horizontal and vertical dimensions of seeding plume) and in what concentrations?
3. What are the effects of stability, wind shear, orographic features and other natural factors on dispersion of the seeding material?

## APPROACH

Modeling is being accomplished on three selected topographic regions where operational cloud seeding is in progress or is being planned: Eagle River Valley, Climax Region; Elk Mountain Region; and San Juan Region. Two types of atmospheric airflow were simulated in the wind tunnel: a neutral stability airflow and barostromatic or stably stratified airflow. Concentration measurements were made over the topographic model for both airflow types using dual radioactive krypton as a passive tracer gas.

Principal Investigator: *J. Cermak*

Discipline Involved: *Civil Engineering*

Beginning Date: *9-2-69* Completion Date: *8-31-71*

Sponsor: *U.S.D.I. - Bureau of Reclamation*



## The Behavior of Negatively Buoyant Gas Plumes

### OBJECTIVES

Recent practice in the air pollution control of fossil-fuel power and heating plants suggests the use of pollution abatement equipment to meet Federal or State pollution standards. Frequently wet flue gas-washing process equipment are used to reduce particulate and SO<sub>2</sub> load levels. Unfortunately the flue gases are always cooled and almost certainly become saturated. Subsequently the release of these saturated gases often is followed by vapor particulate evaporation, cloud cooling, and descent of the gaseous plume to the ground. Plume descent by evaporative cooling of entrained water vapor may increase significantly odor, toxicity, and in some cases explosion potential.

### APPROACH

Dense plume behavior will be studied in the Micro-Meteorological Wind Tunnel at Colorado State University. Measurements of concentration utilizing tracer gases in neutral, stable, and unstable atmospheres will be examined. Modifications to existing plume rise formula will be prepared to allow field computations of wet plume behavior.

Principal Investigator: *R. N. Meroney*

Discipline Involved: *Civil Engineering*

Beginning Date: *5-1-70* Completion Date: *4-30-71*

Sponsor: *HEW - NAPCA*



## Gaseous Plume Entrainment by Obstacles

### OBJECTIVES

This proposal suggests a systematic experimental study of the entrainment problem in the vicinity of rounded building geometries and the effect of thermal stratification on dispersion near building structures. The approach attempts to isolate the peculiarities of such configurations in an effort to make appropriate field predictions possible.

The ultimate objective of this study on gaseous effluent behavior is to help develop a technology which will result in faster, safer, and more economical dispersal of gaseous reactor wastes.

## APPROACH

All measurements will be made in a thick, well developed, turbulent boundary layer within an atmospheric wind tunnel to meet the simulation requirements.

1. The character of the flow about truncated cylinders in shear flow will be examined.
2. Gaseous plume behavior in the vicinity of rounded building structures will be examined.
3. It is proposed to prepare a theoretical analysis containing appropriate empirical formulations to generalize the results of the experimental analysis where possible.

Principal Investigator: *R. N. Meroney*

Discipline Involved: *Civil Engineering*

Beginning Date: *6-15-69* Completion Date: *6-14-71*

Sponsor: *Atomic Energy Commission*

## REGIONAL AND URBAN PLANNING



### Identification of Urban Watershed Units Using Remote Multispectral Sensing (OWRR A-012-COLO)

#### OBJECTIVES

A technique will be developed for spectrum matching of multispectral data acquired by remote sensing to automatically map land use categories on urban watersheds. Test reference reflectance spectra of typical surface coverings will be developed and stored in a computer and available for comparison with data collected from the area by remote sensing.

#### APPROACH

The first phase of the project is identification of land use categories into which an urbanized watershed must be divided for predictive modeling of its water yield. This will be done by field inspection of typical urbanized watersheds.

Land use categories which can be automatically mapped with a remote, airborne multispectral sensor by the technique of spectrum matching will be determined by trial.

Narrow band pass photography will be used to simulate the areal sensor for the purpose of demonstrating the utility of the spectrum matching procedure.

Principal Investigator: *L. D. Miller*

Discipline Involved: *Watershed Science*

Beginning Date: *7-69*

Completion Date: *6-71*



### An Economic Study of the Demand for Outdoor Recreation

#### OBJECTIVES

To provide guidelines for public and private agencies to use in formulating policies affecting the recreational use of regional and area resources. Sub-objectives are:

1. To develop methods or procedures for estimating the demand for and economic impact of recreation.
2. To apply the methods and procedures developed above in determining the characteristics of demand for and impact of outdoor recreation in specific situations.

## APPROACH

1. Apply a modification of the Clawson demand model to develop empirical demand functions for seasonal home sites in mountain areas.
2. Interview a sample of seasonal homeowners in Colorado to collect data on costs, use rates, and socio-economic characteristics of seasonal home users.
3. Explore the effects of differences in natural and man-made characteristics of sites upon demands for these sites.
4. Develop prediction models of the future demand for seasonal home sites in mountain areas.

Principal Investigator: *Richard G. Walsh*

Discipline Involved: *Economics*

Beginning Date: *7-11-69* Completion Date: *6-30-72*



Systems of State Aid to Local Units in  
Colorado and Other Great Plains States

## OBJECTIVES

To consider the problems and feasible alternative systems of providing, administering, and financing state and local public welfare programs, including the possibility of transferring local functions to the state level.

## APPROACH

Conduct a general literature survey on public welfare programs and interview members of the Colorado State Legislative Council and Department of Public Welfare to establish background. Develop a generalized systems analysis approach to determine realistic goals of public welfare programs, methods of achievement, and comparative cost effectiveness. Calculate income redistribution effects of recommended programs.

Principal Investigator: *M. D. Vaughn*

Discipline Involved: *Economics*

Beginning Date: *7-1-68* Completion Date: *6-30-72*



## Economics of Human Capital Transfer and Regional Development Problems, Prospects, and Policy

### OBJECTIVES

To determine the quality characteristics of the stock of human capital on a regional, state, and county basis. To examine human capital quality redistribution patterns on a regional basis and to determine the relation of these interstate and intra-state transfer networks to the economic growth and socio-economic characteristics of areas. To develop an inventory and aggregate index of regional human capital systems and to evaluate the reliability of the regional inventory. To investigate the economic development potential and public policy implications of regional human capital and economic growth interrelations, particularly in relation to rural manpower problems.

### APPROACH

Discounted productivity and income values will be estimated for Colorado human capital transfer systems on a county and multi-county economic area basis and will be related to regional economic growth problems and policies with particular emphasis on rural manpower adjustment processes. Multiple regression analysis will be utilized to develop human capital quality indexes.

Principal Investigator: *Ronald A. Wykstra*

Discipline Involved: *Economics*

Beginning Date: *7-1-70* Completion Date: *6-30-71*



## Criteria for Defining Rural Development Areas

### OBJECTIVES

1. To identify and compare the criteria utilized for defining and the goals associated with establishing development areas.
2. To determine the relationship of selected variables (e.g., organizational structure and functioning, knowledge and communication systems, space utilization patterns, etc.) to decision-making, planning and achievements of area development programs.



3. On the basis of the findings relating to objectives one and two, to develop improved criteria for defining and establishing viable areas for development purposes.

## APPROACH

The number and types of agencies involved in multi-county development activities will be determined. Agency criteria for area delineation will be analyzed. A typology of development areas will be formulated, and one or more areas in Colorado will be studied in depth by a survey of a sample population, by an agency and organization survey, by a community survey, and by a leadership survey.

Principal Investigator: *Emmit R. Sharp*

Discipline Involved: *Sociology and Anthropology*

Beginning Date: *7-1-68* Completion Date: *6-30-71*



**Interaction of Hydrology and Urban Development**

## OBJECTIVES

To determine the interactions between the urbanizing environment and hydrology, especially the effects of sediment erosion, transportation, and deposition. The basic goal is to better understand urban-hydrology problems so that the planning measures can be more effective and easily implemented.

## APPROACH

Specialized monitoring equipment and better data handling techniques for stream- and small-channel measurements are to be developed because of extremely rapid hydrologic variations in the urban areas. Programs to obtain fundamental sediment and hydrologic information from laboratory experiments and from small plots and basins in the urban areas are to be initiated. Increasing emphasis to "Sediment Sources and Sinks--Urbanization" to better evaluate the manner and timing of sediment movement in the construction areas as well as areas downstream.

Principal Investigator: *H. P. Guy*

Discipline Involved: *Civil Engineering*

Beginning Date: *7-1-67* Completion Date: *Open*

Sponsor: *U. S. Geological Survey*

## PUBLIC POLICY



### Economic, Political, and Legal Aspects of Colorado Water Law (OWRR A-013-COLO)

#### OBJECTIVES

This is a study of economic, political, and legal ramifications of Colorado water laws. While overall emphasis will be given to social, physical, and economic interdependence in regard to water resources, specific emphasis will be given to four major aspects. These are:

1. Effects of changes in water law on major water user groups (e.g., individual water rights, agency behavior and procedure).
2. Effects of changes in water law on the Colorado economy (e.g., redistribution and utilization of available water resources).
3. Social and political changes as a result of new legislation, court decisions, and changing public goals.
4. Ramifications of water law with respect to outdoor recreation development potential.

Principal Investigators: *Kenneth C. Nobe, P. O. Foss, J. E. Flack*

Disciplines Involved: *Economics, Political Science, Engineering*

Beginning Date: 7-69

Completion Date: 6-72



### An Economic Analysis of Water Use in Colorado's Economy (OWRR B-059-COLO)

#### OBJECTIVES

1. To delineate the importance of water resources on major sectors of Colorado's economy.
2. To determine the economic interrelationship between the major sectors of Colorado's economy.
3. To estimate the volume of major input and output market flows between Colorado and the rest of the United States with special emphasis on the ten other western states.
4. To estimate the economic impact of assumed water resource changes on the major sectors of Colorado's economy, including both input and output markets.

## APPROACH

Input-output analysis will be used to accomplish objectives one, two, and three. Objective four will be performed with simulation procedures.

Principal Investigators: *D. D. Rhody, Lee Gray*

Discipline Involved: *Economics*

Beginning Date: *7-1-69* Completion Date: *6-30-74*

Disciplines Involved: *Agricultural Engineering,  
Economics, Sociology*

Beginning Date: *7-69* Completion Date: *6-72*



Local Water Agencies, Communication  
Patterns, and the Planning Process  
(OWRR B-051-COLO)

## OBJECTIVES

The primary objective of this research is to determine empirically how planning actually gets done in local water distribution systems. In order to delineate a water planning system this research will focus upon those persons who perform planning functions in local water agencies and their patterns of interactions with other actors in the system. The system will be investigated to determine: the substance and patterns of communications involving planning among individual participants at different levels and points in the water planning system; the type and pattern of involvement of public and private organizations in planning activities; the method used to facilitate the integration of water planning systems and to force back the constraints upon comprehensive, long-range planning in water resource management; and the means and mechanisms used to facilitate communications between actors within water planning systems and with relevant publics external to the water system.

## APPROACH

The water planning system will be delineated empirically through interviews with persons who perform planning functions in representative local water agencies and with those which they communicate. Selection of the local water agencies to be investigated will be completed by means of a stratified sampling design based upon the dimensions of size of agency and the type of user served. Methods of questionnaire design and interviewing will be adapted

from communications research and studies of community decision-making. Data will be collected from areas of high population density along the eastern slope of the Rocky Mountains in Colorado.

Principal Investigators: *Duane Hill, Roy L. Meek*

Discipline Involved: *Political Science*

Beginning Date: *7-69*

Completion Date: *6-71*



**Economic and Institutional Analysis of  
Water Quality Standards and Management  
(OWRR B-042-COLO)**

## OBJECTIVES

This research project will study in depth several agricultural pollution situations in Colorado and will identify for particular reaches of streams, economic optimum methods, and levels of water quality management, including consideration of identifiable externalities involved and alternative means of pollution control. Comparison of the implicit optimum quality standard for the various pollution parameters investigated will indicate the extent to which adopted standards are compatible with efficiency criteria and will provide valuable information to state and federal water pollution control agencies in future reviews of existing water quality criteria.

## APPROACH

Paralleling investigation of the economics of water quality standards will be an examination of the effectiveness of institutions and arrangements for administering and enforcing the Water Pollution Control Program. This examination will describe the legal basis for pollution control; appraise the adequacy of state statutes; assess coordination between units of federal, state, and local government; judge the adequacy of the pollution monitoring system and its adaptability to emerging problems; analyze the procedures for enforcement; and assess the administrative costs of the program. Identification of strengths and weaknesses should reveal desirable modifications for more effectively managing water quality in the state.

Principal Investigator: *Kenneth C. Nobe*

Discipline Involved: *Economics*

Beginning Date: *7-69*

Completion Date: *6-73*



**Consolidation of Irrigation Systems:  
Phase I—Engineering, Legal, and Sociological  
Constraints and Facilitators  
(OWRR B-043-COLO)**

## **OBJECTIVES**

The research program will cover two phases. In the first phase, observation, analysis, and interpretation will be made of the engineering, legal, and sociological factors (both constraints and facilitators) affecting the consolidation of irrigation systems. The second phase, as presently contemplated, would be heavily involved in the social and economic aspects of attaining consolidation, along with legal and engineering requirements.

## **APPROACH**

The first phase will be directed toward the consolidation of irrigation systems:

1. To determine and evaluate the engineering characteristics of the system: magnitude and time-variation of the water supply, physical characteristics of the system, operational methods, and alternative physical and operational systems.
2. To identify and analyze from a legal perspective: whether or not present laws operate as impediments to consolidation, institutional arrangements which control the use of water, legal right of individual users, and to impose legal constraints in consolidation proposals.

The sociological dimension of this research will focus attention on the following organizational arrangement of irrigation companies, perceptions of satisfaction and dissatisfaction by persons associated or affected by irrigation companies, and exploration and delineation of organizational alternatives for consolidation proposals.

**Principal Investigators:** *Gaylord V. Skogerboe, George E. Radosevich, Evan Vlachos*

## WATER SUPPLY



### Water Yields from Shallow Mountain Soils in Relation to Forest Cover

#### OBJECTIVES

To determine the consumptive uses of water under varying conditions of forest cover on thin immature mountain soils. To derive a rating system for water yields from the soils.

#### APPROACH

Establishment of the annual water budget of the soil and the establishment of estimates of water use by the forest and losses by other soil moisture depletion functions. Edaphic environment will be analyzed. Climatic factors will be measured. Biological activity of the forest will be monitored. Predictive multiple regression equations for potential water yield will be structured. Indexes of potential water yield will be attempted.

Principal Investigators: *E. W. Mogren, H. L. Teller*

Discipline Involved: *Forest and Wood Sciences*

Beginning Date: *7-1-69* Completion Date: *6-30-73*



### Quantification of Water-Soil-Plant Relations for Efficient Water Use

#### OBJECTIVES

1. To determine relations of plant water stress to metabolic processes, growth, and composition.
2. To utilize quantitative water-soil-plant relations research to improve criteria for scheduling irrigations to achieve optimum water use efficiency.

#### APPROACH

Controlled environment will be used to evaluate methods for developing and maintaining water stress levels in plants. The relative influence of water stress *per se* and the mechanical methods used in developing stress will be evaluated in terms of plant response. Extrapolation of laboratory results to field conditions will be evaluated. Emphasis will be directed toward measuring the influence of time and degree of plant water stress on net photosynthesis and transpiration in order to evaluate water use efficiency by plants.

Principal Investigator: *R. E. Danielson*

Discipline Involved: *Agronomy*

Beginning Date: *7-1-69* Completion Date: *6-30-74*



### Water Resources Optimization

#### OBJECTIVES

To research methods of optimizing the water resources of Colorado. This will include:

1. Study of chemical and other means of reducing seepage from canals, small reservoirs, and storage ponds.
2. Study of consolidation of water conveyance systems to further reduce seepage losses, increase the efficiency of water deliveries, and alleviate problems caused by existing canals located in areas of urban growth.

#### APPROACH

The above work will include both field and laboratory phases. It is planned that the work will include applied research, development, and demonstration aspects.

Principal Investigator: *E. V. Richardson*

Discipline Involved: *Civil Engineering*

Beginning Date: *7-1-67* Completion Date: *6-30-72*



### Hydrometeorology

#### OBJECTIVES

Prediction of Colorado River runoff through meteorological techniques; analysis of storms passing over the Rockies concerning large-scale aspects of weather modification in these storms; experimentation with snow fencing in the high Rockies to channel snowdrift into glacial cirques.

#### APPROACH

A computational technique for estimating snow accumulation during winter and the role of strong

evaporation situations in upsetting preliminary water yield estimates will be applied on a basis of "operational observation" next season. Additionally, the present investigation of the water cycle in coordinates moving with major storm systems, and of its role in the energy balance of storms will be continued for two more years. This will show the potential for weather modification as seen from large-scale computational work, and we shall also obtain an estimate of possible influences by man on large storms. Finally, the snow fencing work already done in conjunction with OWRR is scheduled to proceed to larger field experiments in the next two winters, based on the experience gained in the last two years in central Colorado. The new experiments should also lead to an estimate of the financial practicability of collecting additional water by snow fencing.

Principal Investigators: *H. Riehl, J. Rasmussen*

Discipline Involved: *Atmospheric Science*

Beginning Date: *7-1-68* Completion Date: *6-30-73*



### **Irrigation Flow Meters and Canal Structures**

#### **OBJECTIVES**

It is proposed:

1. To develop a new flow measuring device which serves other functions as well.
2. To study sources of errors in flow measuring devices.
3. To study head losses in metering devices and other canal structures.
4. To investigate the inverted siphon as a "safety factor" structure.

Principal Investigator: *Herman J. Koloseus*

Discipline Involved: *Civil Engineering*

Beginning Date: *11-8-67* Completion Date: *7-1-72*



### **Mathematical Modeling of Small Watershed Floods**

#### **OBJECTIVES**

The objective is the characterization of the response of small watersheds to rainfall in terms of mathematical relations among the physical para-



meters of the watershed. These relations will then be used to predict the runoff hydrographs for floods from small watersheds.

## APPROACH

Work will include: statistical correlation of watershed parameters with runoff, investigation of models developed from concepts of physical processes at work in runoff, and coordination with a related project involving a one-acre experimental facility for rainfall-runoff experiments. Data from natural flood events will be added to the existing Small Watershed Data File.

Principal Investigator: *V. M. Yevjevich*

Discipline Involved: *Engineering*

Beginning Date: *8-67*

Completion Date: *8-71*



### Hydraulics of Surface Irrigation

## OBJECTIVES

To provide fundamental surface-irrigation design understanding through investigation of the hydraulic characteristics of surface flow.

## APPROACH

Extensive field data have been collected from irrigation furrows on many sites covering a wide range of soil conditions. Analysis will be completed, and a comprehensive technical publication will be produced incorporating the Regional Project findings.

Principal Investigators: *D. F. Heermann,*  
*Norman A. Evans*

Discipline Involved: *Agricultural Engineering*

Beginning Date: *7-1-69*

Completion Date: *6-30-71*



### Prediction of Water Yield from Small Rocky Mountain Watersheds

## OBJECTIVES

1. To determine the hydrologic characteristics of the various physiographic, edaphic, and biotic components of typical small watersheds in the Rocky Mountain chain with respect to yield.

2. To determine the effect of the various combinations of site variables on the precipitation-runoff relationship and devise prediction equations for this relationship.
3. To identify specific areas within the watershed which have potential for treatment to increase water yield, and, on the basis of present knowledge, estimate the maximum increase which could be anticipated.

## APPROACH

A small typical mountain watershed will be selected initially and subdivided into logical response units based on soils, vegetation, topography, geology, and precipitation inputs. Storage, losses, and surpluses will be determined for each defined response unit, and excess water will be routed through the watershed and combined on the computer to estimate yield.

Principal Investigators: *W. D. Striffler, J. R. Meiman*

Discipline Involved: *Watershed Science*

Beginning Date: *7-16-69* Completion Date: *6-30-72*



Experimental Investigation of Small  
Watershed Floods

## OBJECTIVES

To increase the understanding of processes making up watershed response and to improve our ability to apply knowledge of the processes to the estimation of the response of real watersheds.

## APPROACH

The approach to the investigation is threefold: the design; the construction; and the operation of a rainfall-runoff experimental facility, one acre in size, for the purpose of observing prototype-scale response of a watershed under controlled conditions.

Principal Investigators: *George L. Smith,  
V. M. Yevjevich*

Discipline Involved: *Civil Engineering*

Beginning Date: *7-1-67* Completion Date: *7-1-72*



**Theory and Experiments in the  
Prediction of Small Watershed Response  
(OWRR B-054-COLO)**

**APPROACH**

Mathematical models of watershed response to flood producing rainfall are to be verified in the one-acre CSU outdoor experimental rainfall-runoff facility. The mathematical models will be optimized using the experimental facility. The optimized mathematical model will be used to predict the observed flood from a small natural watershed. The CSU rainfall-runoff facility is regarded as a bridge between the small-scale laboratory model having "low noise" output and the natural watershed having "high noise" due to neglected or incorrectly measured variables. The sensitivity of the predicted runoff to various types of sampling errors will be studied in the second phase of the project.

Principal Investigators: *E. F. Schulz, V. M. Yevjevich*

Discipline Involved: *Civil Engineering*

Beginning Date: *7-70*

Completion Date: *6-71*



**Multivariate Analysis of Small Watershed  
Rainfall-Runoff Relations  
(OWRR A-009-COLO)**

**OBJECTIVES**

The purpose of the project is to select an effective set of variables for rainfall-runoff relations and with these variables derive rainfall-runoff relations for small watersheds to test their validity for various regions, especially arid and semiarid. An extensive research data assembly for small watershed floods will be divided into two data sets of approximately equal size. The first set of data will be used to derive relationships, and the second will be used to evaluate them with independent information.

**APPROACH**

Multivariate statistical analyses will be used to analyze the first data set. In particular, a principal component analysis will be the first step in determining the most appropriate groupings of the variables. These results will be studied to find physical justifications for factor groupings, and the relationships may be modified by a factor analysis.

A number of prediction equations will be generated with different numbers of independent variables. The equations will be tested in a simulation procedure to generate runoff estimates under varying degrees of lack of information. These estimates will be tested by comparison with the second set of data from the small watersheds file.

Principal Investigator: *E. F. Schulz*

Discipline Involved: *Civil Engineering*

Beginning Date: 7-69

Completion Date: 6-72



Snow Survey Research

## OBJECTIVES

To obtain enough measurements of the snow pack in Colorado and New Mexico to make volume and peak flow forecasts of all the major streams in these states. To provide snow data including total amount on the ground at any given time, rate of fall, and duration of storm for the evaluation of the three Atmospheric Water Resource Research Projects.

## APPROACH

Measure 200 snow courses, 10 precipitation gages, and 44 soil moisture stations at least monthly from February through April. Maintain automatic snow pillow systems in the Park Range and Durango areas in Colorado and Cuba area in New Mexico to provide daily information.

Principal Investigator: *J. Washichek*

Discipline Involved: *Agricultural Engineering*

Beginning Date: 1-1-60

Completion Date: *Open*

Sponsors: *State of Nevada, State of New Mexico, State of Colorado, Various Industrial Firms, U.S.D.I.—Bureau of Reclamation, U.S. Soil Conservation Service*



Water Rights-State of Colorado

## OBJECTIVES

1. To review data requirements for the tabulation with the State Engineer.

2. To jointly select data to be keypunched and tabulated.
3. To develop an edit program to check input data for obvious errors.
4. To write a sort program to list data in proper order.
5. To prepare the necessary tabulations in the proper format.

## APPROACH

1. Assist the State Engineer in the Division of Water Resources in the preparation of the tabulation of all adjudicated water rights in Colorado.
2. Utilize the computer to sort the data in the proper order and provide the necessary lists.

Principal Investigator: *Robert Longenbaugh*

Discipline Involved: *Civil Engineering*

Beginning Date: *5-13-70* Completion Date: *6-30-70*

Sponsor: *State of Colorado Division of Water Resources*



Water Management Research in Arid and Subhumid Lands

## OBJECTIVES

To enhance the University's capacity to respond to specific problems of international development related to arid lands and to advance its level of competence in the appropriate disciplines. The general objective is to increase food production in the arid and subhumid lands of less developed countries.

## APPROACH

These objectives were pursued through the following departments: Agricultural Engineering, Agronomy, Civil Engineering, Economics, Political Science, and Sociology. The studies related to the above objectives have been initiated at CSU and are being transferred to West Pakistan. The total research effort is coordinated by the Program Director, Professor M. L. Albertson.

Principal Investigator: *M. L. Albertson*

Discipline Involved: *Civil Engineering*

Beginning Date: *6-28-68* Completion Date: *6-27-73*

Sponsor: *Agency for International Development (AID)*



## Optimum Utilization of Water Resources

### OBJECTIVES

To strengthen the already existing competence of CSU in water delivery and removal systems and in development of institutions which are relevant to the various aspects of optimum utilization of water resources.

### APPROACH

The objectives are accomplished through the following six departments: Agricultural Engineering, Agronomy, Civil Engineering, Economics, Political Science, and Sociology. Each department developed a program and requested funds to pursue their program. Funds are administered and allocated through the Program Director to insure coordination and compliance with grant objectives.

Principal Investigator: *M. L. Albertson*

Discipline Involved: *Civil Engineering*

Beginning Date: *5-23-69* Completion Date: *5-22-74*

Sponsor: *Agency for International Development (AID)*



## Management of Colorado Mountain Lands for Increased Water

### OBJECTIVES

1. To test snowmelt acceleration materials and techniques on a large-scale (10-acre cirque glacier) treatment basis.
2. To complete field testing of continuous method of gaging streamflow previously developed.
3. To evaluate the water yield benefit expected from operational conversion of lodgepole pine forest to herbaceous vegetation.

### APPROACH

1. Runoff from two segments of a 10-acre cirque glacier will be compared for calibration purposes. One segment will be treated with snowmelt acceleration materials if sufficient calibration is obtained.

2. Hydrographs obtained by the continuous dye dilution method are compared to hydrographs obtained from sharp-crested weirs on two Colorado mountain streams.
3. Three pairs of plots approximately three acres in size will be compared before and after the center one-acre portion on each of three plots is clearcut.

Principal Investigator: *R. Dils*

Discipline Involved: *Watershed Science*

Beginning Date: *7-1-68* Completion Date: *8-31-73*

Sponsor: *U.S.D.I. - Bureau of Reclamation*



### Hydrologic Suitability of Drainage Basins to Weather Modification

#### OBJECTIVES

The objective of the project is to develop definite techniques:

1. To determine the hydrologic suitability of regions considered for precipitation management.
2. To evaluate the results of future programs in general and of the planned pilot program in the Upper Colorado River Basin in particular.

#### APPROACH

Techniques combining theory of optimization with multivariate tests of hypotheses are the key procedures for this research.

In addition, much effort has been expended to develop a practical, efficient, and exhaustive data system for the Upper Colorado River Basin.

Principal Investigator: *H. J. Morel-Seytoux*

Discipline Involved: *Civil Engineering*

Beginning Date: *7-1-68* Completion Date: *6-30-71*

Sponsor: *U.S.D.I. - Bureau of Reclamation*



### Evaporation of Water as Related to Wind Barriers (OWRR E-015-COLO)

#### OBJECTIVES

The evaporation of water from soil and water surfaces and from plants is intimately associated with the local wind characteristics such as turbulence, mean velocity, temperature, and water vapor content.

Properly designed and located wind barriers and soil surface corrugations show considerable promise for controlling the local habitat with respect to turbulence and mean wind velocity or in other words the local transfer coefficients.

## APPROACH

By means of experimental measurements over simulated corrugated surfaces with and without wind barriers placed in a special wind tunnel:

1. Determine the local heat and mass transfer coefficients over the surface of corrugated areas. The variation of these coefficients for a wide range of corrugation configuration, spacing, depth, and orientation relative to the mean wind direction is to be obtained. In addition to direct measurement of the transfer coefficients, the local mean wind distribution and turbulence characteristics are to be determined.
2. Determine the local heat and mass transfer coefficients over surfaces which are bordered by obstacles such as tree rows, hedge rows, stubble strips, and solid or semi-solid barriers. The variations of these coefficients for a variety of barrier structures, row spacing, and height is to be obtained. Local mean wind distributions and turbulence characteristics are to be measured in addition to the local transfer coefficients.
3. Develop analytical methods, using the experimental data acquired, which will assist in the design of wind barriers for planning water conservation measures.

Principal Investigators: *J. E. Cermak, W. E. Marlatt*

Disciplines Involved: *Civil Engineering, Atmospheric Science*

Beginning Date: *7-1-67* Completion Date: *6-30-71*



**Improvements in Moving Sprinkler Irrigation Systems for Conservation of Water (OWRR B-039-COLO)**

## OBJECTIVES

Infiltration rates of soils under sprinkler irrigation will be studied, particularly as they are affected by time-varying application rates of the type which are found under moving sprinkler systems.

## APPROACH

Design and operational guidelines for the various moving systems will be established by mathematical



simulation. The effectiveness of existing types of sprinkler systems will be compared with respect to application rates, uniformity of water application depths, and ability to match the intake characteristics of various types of soils. Modifications will be recommended on the basis of the results of this study.

An economic analysis will be made of existing sprinkler system designs and modifications of existing equipment in terms of their irrigation efficiency and water conservation value.

Principal Investigators: *Donald L. Miles,*  
*Norman A. Evans*

Discipline Involved: *Agricultural Engineering*

Beginning Date: 7-69

Completion Date: 6-72



**A Systematic Treatment of the Problem  
of Infiltration (OWRR B-033-COLO)**

## OBJECTIVES

The overall objective of the research is to develop a mathematical model of infiltration capable of responding to any spatial and temporal pattern of rainfall or its lack. In this form the model would be readily capable of integration into a general model simulating the hydrologic response of a watershed.

In a first phase the objectives will be more limited. In essence the two principal objectives are:

1. The development of a one-dimensional model of water infiltration into a soil column under realistic conditions of varying water supply at the surface, non-uniform initial moisture conditions, heterogeneous soil characteristics, and the effect of hysteresis.
2. The development of a less general two-dimensional model of water infiltration to model primarily the influence of spatial variation of the available water supply on infiltration.

Principal Investigators: *H. J. Morel-Seytoux,*  
*P. Todorovic*

Discipline Involved: *Civil Engineering*

Beginning Date: 7-68

Completion Date: 6-71



## Rocky Mountain Orographic Cloud Precipitation and Modification

### OBJECTIVES

The general objective of this research is to acquire an increasingly complete understanding of cold orographic clouds, their associated precipitation, and the changes in their characteristics and processes when artificial nuclei are introduced. This includes the determination of the precipitation potential from cloud modification and the development and evaluation of technology required for implementation of operational programs.

### APPROACH

The basic procedures followed to achieve the program objectives include a step-by-step investigation of cloud processes and their modification. Specific emphasis during this period has been direct to: refinement of the physical model of orographic cloud processes, an extension of the statistical analyses of the precipitation data for randomly selected seed and no-seed days, ice crystal and ice nuclei analyses for verification of the model, comparison of particulate transport characteristics in the field with those over a laboratory model, water vapor balance determinations as parcels of air traversed the Continental Divide, and analyses of precipitation data up to several hundred miles downwind of the randomized seeding.

Principal Investigator: *L. Grant*

Discipline Involved: *Atmospheric Science*

Beginning Date: *18-1-69* Completion Date: *9-30-71*

Sponsor: *National Science Foundation*



## Adaptation Program for Atmospheric Water Resources

### OBJECTIVES

To design a pilot program of applied cloud seeding for increasing water supplies in the Colorado River Basin based on contemporary knowledge. Evaluation for such a program is to include a reasonable estimate of the water produced from the program at stated

confidence levels and an assessment of the technology employed.

## APPROACH

The program design is being based on the research findings from the CSU Climax Colorado Experiment.

Principal Investigator: *L. Grant*

Discipline Involved: *Atmospheric Science*

Beginning Date: *4-1-68* Completion Date: *6-30-71*

Sponsor: *U.S.D.I. - Bureau of Reclamation*



## Hydrometeorology

## OBJECTIVES

1. Studies of the atmospheric water balance--the Colorado River Basin. The atmospheric water balance yields the exchange of water and water vapor at the earth-atmosphere interface through the spatial and time distributions and fluxes of water vapor in the atmosphere over the basin. Our aim is to determine the accumulation and losses of water in the basin as a function of time (daily series). We determined the relationship between winter season accumulation and the resulting runoff. We further study the magnitude of the daily evaporation (sublimation) occurring over the basin so that the effect of this parameter on the water resource is estimated.
2. Studies of the condensation-precipitation processes in orographic clouds and synoptic scale cyclones. This research is designed to evaluate the efficiency of these clouds and storms so that we may evaluate the effect of cloud seeding on the physical system. We derive from a numerical analysis the rates of precipitation and condensation as a function of temperature and the efficiency of the cloud. We find that the efficiency of the cloud varies greatly between samples. This efficiency depends upon cloud nuclei, cloud temperature, and season.

Principal Investigator: *J. Rasmussen*

Discipline Involved: *Atmospheric Science*

Beginning Date: *1965*

Completion Date: *Open*



## Investigation for Flood Protection of Bridges

### OBJECTIVES

1. Channel stabilization in the vicinity of and downstream of culvert outlets.
2. Channel stabilization in the vicinity of and downstream of bridges.
3. The use of special methods and techniques where there is no gravel or rock and where special problems arise.

### APPROACH

Utilized three different sizes of laboratory flumes to obtain data. Subsequently, limited field data were collected to help establish validity of results.

Principal Investigator: *D. Simons*

Discipline Involved: *Civil Engineering*

Beginning Date: *2-16-66* Completion Date: *2-16-70*

Sponsor: *Wyoming State Highway Commission*

## GROUNDWATER



### Dynamics of Flow into Drainage Facilities

#### OBJECTIVES

To analyze and describe the subsurface movement of water and those factors which affect it in the flow region of drainage facilities.

#### APPROACH

Two-dimensional physical models will be used to determine sensitivity of drainage behavior to soil hydraulic parameters. The accuracy with which these parameters must be determined to give results consistent with accuracy inherent in the model will be found. Results from model studies will be used to evaluate mathematical simulation of two-dimensional unsteady drainage.

Principal Investigator: *A. T. Corey*

Discipline Involved: *Agricultural Engineering*

Beginning Date: *7-1-69*    Completion Date: *6-30-74*



### Measurement Prediction and Control of Soil in Arid Soils Movement Water Movement in Arid Soils

#### OBJECTIVES

1. To apply soil water movement theories to real situations with emphasis on land area bases.
2. To develop practical and easily applied instruments and techniques for evaluating soil water content, potential, and flow.

#### APPROACH

Diffusion rates of water vapor through gravel and sand layers will be used to provide first estimates of effects of such layers on retarding evaporation. Such treatments will then be evaluated under field conditions--including measurement of downward water movement in the profiles.

Well logs in the state engineers' office will be used to estimate texture and water holding capacity of strata above the water table and time required for recharge to be effective. Effects of surface treatments on water use by plants will be evaluated to develop the best treatments for increasing water use efficiency.

The centrifuge-analytical balance method for measuring hydraulic conductivity of unsaturated core samples will be developed and evaluated as a method for estimating groundwater movement.

Principal Investigator: *William Kemper*

Discipline Involved: *Agronomy*

Beginning Date: *7-1-69*      Completion Date: *7-1-74*



Groundwater Resources

## OBJECTIVES

1. To develop feasible techniques for efficient development and management of groundwater aquifers.
2. To investigate the applicability of management and development of techniques deemed feasible to the various groundwater situations in Colorado and other areas.
3. To train young engineers and scientists in the latest advancements for analysis and management of groundwater resources through the graduate research program.
4. To serve as advisers to the Colorado Groundwater Commission, Colorado Water Conservation Board, State Engineers Office, and other state and local water agencies on groundwater problems.

## APPROACH

Continuing efforts will be directed toward developing and testing improved techniques for more adequate simulation and analysis of groundwater systems. These techniques will include both deterministic and probabilistic approaches and will be concerned with both hydraulics and water quality factors. Management studies will be made on Colorado groundwater reservoirs using the continually improved techniques and physical data.

Review and analyses of water table fluctuations will be continued, with timely publication of data for the major Colorado aquifers.

Principal Investigator: *Daniel K. Sunada*

Discipline Involved: *Civil Engineering*

Beginning Date: *7-1-61*      Completion Date: *7-1-72*



An Experimental Study of  
Soil Water Flow  
Systems Involving Hysteresis  
(OWRR A014-COLO)

## APPROACH

Hysteresis in the water content and permeability functions will be determined by experimental observations on several soil materials. Gamma attenuation apparatus and strain gauge pressure transducer tensiometry will be employed in making the measurements. Both unsteady state and static equilibrium observations will be made on the moisture content functions.

One-dimensional vertical flow columns of the selected soils will be programmed through sequences of infiltration, redistribution-evaporation-drainage, and infiltration. Measurements of water content and hydraulic and pressure head will be made using the above-mentioned techniques. Depths of wetting during infiltration, the duration of redistribution process, and the intensity of evaporation will be varied. The gas phase pressure will be measured, and the effects of gas phase flow will be examined. The observed behavior of the flow system will be compared with the predicted behavior based on one or more of the schemes for solving the flow equation for hysteretic flow, and an evaluation of the prediction scheme will be made.

Principal Investigator: *Arnold Klute*

Discipline Involved: *Agronomy*

Beginning Date: *7-70*      Completion Date: *6-30-73*



## Similitude for Flow of Two Fluids in Porous Media

### OBJECTIVES

1. To examine a theory for modeling two-phase fluid flow in porous media.
2. To determine to what extent variations in soil air pressure might affect flow of water in soils, particularly flow associated with infiltration and drainage.

### APPROACH

The flow of both liquid and air during infiltration into porous media columns was studied experimentally. The distribution of pressure and saturation of the two fluids was measured as a function of time. A mathematical description of the process as a two-phase flow phenomenon has been developed.

Principal Investigator: *A. T. Corey*

Discipline Involved: *Agricultural Engineering*

Beginning Date: *5-1-68* Completion Date: *4-30-71*

Sponsor: *National Science Foundation*



## Measure of Volume of Water Pumped from Irrigation

### OBJECTIVES

To evaluate the possibility of computing the volumes of water pumped from power records:

1. To determine cost of such a method.
2. To determine what accuracy might be expected.
3. To determine how much manpower would be required.

### APPROACH

Utilizing pumping plant efficiency data collected in 1964-65, it was possible to evaluating the accuracy of the technique, cost, and manpower requirements. Some engineering estimates were also needed.

Principal Investigator: *Robert Longenbaugh*

Discipline Involved: *Civil Engineering*

Beginning Date: *1-1-70* Completion Date: *4-3-70*

Sponsor: *State of Colorado Division of Water Resources*





**Geohydraulics at the Unconformity  
Between Bedrock and Alluvial Aquifers  
(OWRR B-022-COLO)**

**OBJECTIVES**

The proposed research is to develop principles and methods for estimation of water transfer at bedrock-alluvium contacts in groundwater basins.

Fundamental to the concept of an alluvial basin is the isolation of water. That is, neither surface water nor groundwater should flow from one basin to another. If groundwater basins can be designated such that water transfer is minimized, then it is feasible to determine availability of water in each basin and to develop laws and management policies for water use.

**APPROACH**

Three designated groundwater basins in Colorado will be studied to determine the magnitude of water flux into or out of the underlying bedrock. Considerable data are available on bedrock and water level elevations within each of the three basins.

Procedures for the study will include: use of digital computer models and trend surface analyses, piezometric studies in both bedrock and alluvial aquifers, and general geologic and geophysical techniques.

Principal Investigators: *J. P. Waltz, Daniel K. Sunada*

Disciplines Involved: *Geology, Civil Engineering*

Beginning Date: *7-68*

Completion Date: *6-72*



**Groundwater Recharge as Affected by  
Surface Vegetation and Management  
(OWRR B-013-COLO)**

**OBJECTIVES**

To determine contribution to groundwater of range and cultivated land under semiarid climate; to evaluate changes in contribution to groundwater caused by treatments imposed on vegetation and soil surface; and to relate plant species, microrelief, and soil texture as factors influencing groundwater recharge.

## APPROACH

Core samples for determination of hydraulic conductivity will be taken at depths below the root zone and above the water table influenced zone where the hydraulic gradient may be assumed to be unity. Downward flow rates can then be estimated directly. Hydraulic conductivity will be determined using newly developed techniques involving gravimetric determination of flow rates following centrifugation of sealed core samples. Treatments, including soil surface modification by tillage and mulches, and vegetation modification by herbicides will be evaluated. Soil moisture contents will be monitored by the neutron scatter method, and consumptive use data will be obtained for various crops.

Principal Investigators: *R. E. Danielson,*  
*W. D. Kemper, K. G. Doxtader*

Discipline Involved: *Agronomy*

Beginning Date: *7-1-67* Completion Date: *6-30-71*

## WASTE DISPOSAL



### Animal Waste Management with Pollution Control

#### OBJECTIVES

To further develop animal waste management systems to control odors and toxic materials in air, and organic materials, organisms, nutrients, and chemicals in water and soil, compatible with efficient livestock production and cropping practices in the areas of:

1. Collection, transport, and management of wastes.
2. Treatment and conditioning of wastes.
3. Utilization and/or disposal of wastes.
4. Biological and physical analysis and integration of systems from 1, 2, and 3 above.

#### APPROACH

Runoff evaporation and solids disposal will be modeled in a simulated feedlot and field tested. The effects of feeds, additives, and bedding will be done with paired animal experiments. Enzyme activities affecting manure degradation will be determined, and the results will be used in laboratory modeling of these enzyme systems for feedlot management. Volatile pollutants in the air above feedlots will be collected on adsorbents, eluted by solvents, identified and characterized by various qualitative and quantitative methods, and their sources and causes of production determined.

Principal Investigators: *S. M. Morrison, R. P. Martin, J. C. Ward*

Disciplines Involved: *Microbiology, Biochemistry, Civil Engineering*

Beginning Date: *7-1-70* Completion Date: *6-30-75*



### Combined Cooling and Bio-treatment of Beet-sugar Factory Condenser Water Effluent (OWRR A-008-COLO)

#### OBJECTIVES

The objective is to establish the feasibility of reducing thermal and organic pollution from beet-sugar factories by cooling towers in a closed system in which biological oxidation of sugars and other organics is induced and maintained.

## APPROACH

The primary procedure will be laboratory determination on actual and synthetic samples of beet-sugar condenser water effluents under various conditions of temperature, concentration, recirculation rate, separation of sludges, etc. After batch experiments have yielded the necessary data, a small-scale flow apparatus will be assembled and will be operated to determine the extent to which the primary data can be applied in practical design.

Principal Investigator: *George O. G. Lof*

Discipline Involved: *Civil Engineering*

Beginning Date: 7-69 Completion Date: 6-71



The Mechanisms of Waste Water  
Treatment at Low Temperature  
(OWRR A-007-COLO)

## OBJECTIVES

The primary purpose of the study is to identify and evaluate the biological, chemical, and physical factors that affect waste water treatment in areas and communities with prolonged periods of low temperature. This information, unknown at present, is essential to provide the criteria for the ultimate objective of waste water treatment plant design for cities at higher altitudes in Colorado, as well as cities at high latitudes of the United States.

## APPROACH

The study will consist of three phases: the evaluation of the biological, chemical, and physical factors, laboratory bench top treatment systems, and the development of design criteria to incorporate new information developed under the first two phases.

Under the first phase, the following studies will be initiated:

1. Isolation, identification, modification, and adaptation of sewage treatment microorganisms to the cold environment.
2. Determination of the optimal microbial flora for waste digestion at temperatures between 0 degrees and -20 degrees C.
3. Modification of the waste water as a microbial substrate to provide optimal digestion rates.

4. Determination of action of chlorine or other final disinfectant agents on potential pathogens at low temperatures.

Principal Investigators: *S. M. Morrison, J. C. Ward*

Disciplines Involved: *Microbiology, Civil Engineering*

Beginning Date: *7-69*

Completion Date: *6-72*



### **Study of Improvement of Evaporation of Brines**

#### **OBJECTIVES**

The research objective is the development of methods for increasing evaporation of waste brines from inland desalting plants in order to decrease the cost of disposal. The method being examined is the spraying of brine from nozzles distributed over the surface of a shallow pond, evaporation being compared with natural pond surface evaporation.

#### **APPROACH**

1. Theoretical study of evaporation from droplets produced by spray nozzles.
2. Laboratory experiments with single nozzles spraying water into air passing through wind tunnel.
3. Outdoor measurements of evaporation from spray nozzle system over shallow pond of about a 10,000 square foot area.

Principal Investigator: *George O. G. Lof*

Discipline Involved: *Civil Engineering*

Beginning Date: *6-10-69*

Completion Date: *6-9-71*

Sponsor: *U.S.D.I. - Office of Saline Water*



### **Vegetative Restoration of Mine Tailings, Waste, and Spoils**

#### **OBJECTIVES**

To determine treatments, techniques, and species suited for establishing vegetation and productive land use on coal mine spoils in Colorado.

## APPROACH

1. Field, greenhouse, and laboratory work to characterize vegetation and spoils on successful reclamation work.
2. Field studies on vegetation establishment on problem spoil areas.

Principal Investigator: *William A. Berg*

Discipline Involved: *Agronomy*

Beginning Date: *7-25-69* Completion Date: *6-30-71*

Sponsor: *Various Coal Companies*

## FISHERY – WILDLIFE – RECREATION



### Assessing Big Game Management Alternatives Through Bio-economic Models

#### OBJECTIVES

To develop, test, and refine models simulating existing relationships and values of resources related to big game production and use. To determine bio-economic relationships and values in big game production and use. To demonstrate application and related public policy decisions. To devise a bio-economic model for values of big game to ranches of the Western Slope, Colorado, especially related to mule deer.

#### APPROACH

Data will come from county and state statistics, an interview with each rancher, and biologic data from a cooperative study underway with other public agencies. Will do 100% coverage in Grand County and sample of other western slope counties. Will test applicability of the model and the data by inserting a series of logical variations into the computerized model and noting whether predicted biological and economic results are reasonable.

Principal Investigator: *Harold W. Steinhoff*

Discipline Involved: *Fishery and Wildlife Biology*

Beginning Date: *6-27-67* Completion Date: *6-30-72*



### Value of Early Water for Waterfowl Production

#### OBJECTIVES

1. To determine what effect the application of water on a waterfowl breeding ground prior to the normal irrigation season will have on waterfowl production and use.
2. To determine the cost benefit ratio between an area that is supplied early water from supplemental sources and an area that receives a normal supply of water during the regular irrigation season.
3. To determine the progress of ecological succession on the study areas during the course of the study and its relationship to waterfowl production and use.

4. To measure the slope of barrow-pit edges and barrow-pit depths.
5. To determine vegetative composition of the study areas.

## APPROACH

Waterfowl production was determined by breeding pair counts, nesting surveys, and brood counts. To determine the cost-benefit ratio, detailed records were kept on the amount of labor involved in water application, mileage, and cost of water.

Vegetative changes resulting from flood irrigation were determined by three vegetation studies: systematic quadrat study, random cluster quadrat study, and an elevated photo inventory.

Barrow pits were systematically surveyed to compare slopes and depths. Vegetation maps were made to compare vegetation type acreage changes since the 1962 mapping.

Principal Investigator: *F. Glover*

Discipline Involved: *Cooperative Wildlife Unit*

Beginning Date: *12-31-64* Completion Date: *12-31-72*

Sponsor: *U.S.D.I. - Bureau of Sport Fisheries*



Pneumonia in Rocky  
Mountain Bighorn Sheep

## OBJECTIVES

1. To prepare a suitable vaccine for use in controlling pasteurellosis in bighorn sheep.
2. To evaluate immunological response of laboratory animals and bighorn sheep to prepared pasteurellosis vaccines.

## APPROACH

Bacteria associated with pasteurellosis disease in bighorn sheep were collected from apparently normal and dead bighorn sheep. Killed bacteria have been prepared into vaccines and the immune response tested on seven isolates.

Principal Investigator: *G. Post*

Disciplines Involved: *Wildlife Biology, Microbiology*

Beginning Date: *5-1-69* Completion Date: *4-30-72*

Sponsor: *Rachelwood Wildlife Research Preserve*





## Uptake, Excretion, and Distribution of Zinc <sup>65</sup>Zn by the Mallard Ducks

### OBJECTIVES

To determine <sup>65</sup>Zn uptake and retention parameters in the mallard duck. To determine the influence of mallard age and sex, egg production, feather molt, and the season of the year on <sup>65</sup>Zn kinetics in the mallard.

### APPROACH

Captive mallard ducks were dosed (orally and injected intramuscularly) with ZnCl<sub>2</sub>. Retention of <sup>65</sup>Zn in the mallards and <sup>65</sup>Zn deposition in eggs and feathers of the mallards were monitored through the detection of gamma-ray emissions from <sup>65</sup>Zn.

Principal Investigator: *F. Glover*

Discipline Involved: *Cooperative Wildlife Unit*

Beginning Date: *9-15-67* Completion Date: *3-14-70*

Sponsor: *Atomic Energy Commission*



## Study of the Urial Ram of the Elburz Mountain

### OBJECTIVES

To determine the ecology and related behavior of the Urial sheep of the Mohammad Reza Shah Wildlife Park in Northeast Iran.

### APPROACH

Graduate research assistant G. Kowalski spent the period from June 1969 to June 1970 on the study area recording data on the sheep, vegetation, and other factors. He spent the summer and fall quarter analyzing data and initiating his reports.

Principal Investigator: *E. Deckers*

Discipline Involved: *Wildlife Biology*

Beginning Date: *10-1-68* Completion Date: *9-30-70*

Sponsor: *Iran Government*



## Toxicity Studies on Salmonid Fishes

### OBJECTIVES

To determine the sublethal effect of malathion on three salmonid species. To determine the physical effect of reducing brain acetylcholinesterase on the salmonid species.

### APPROACH

Malathion concentrations were metered into four groups each of rainbow trout, brook trout, and coho salmon until brain acetylcholinesterase levels were reduced to 75% of normal in one group, 45% of normal in another group, and 25% of normal in a third group. The fourth group remained with a full complement of the enzyme. Representative samples of each group were then subjected to physical activity in a stamina tunnel, and a physical activity index was determined. Brain acetylcholinesterase was allowed to return to normal and a final activity index calculated to determine if exposure had caused permanent impairment of physical ability.

Principal Investigator: *G. Post*

Discipline Involved: *Fisheries*

Beginning Date: *9-1-68*      Completion Date: *3-1-70*

Sponsor: *U.S.D.I. - Bureau of Sport Fisheries*



## Fingerling Fathead Minnows

### OBJECTIVES

The primary objective of this study is to evaluate the effect of harvesting completeness and frequency on production of fingerling fathead minnows. The second objective is to determine the comparative survival of progeny removed by seining and draining.

## APPROACH

Three harvesting procedures were used to remove fingerling production. The methods were: one complete harvest at the end of the summer, periodic partial removal by seining, and periodic complete removal by draining. Each treatment was duplicated. A sex ratio of five females to one male at a density of 19,200 brood fish per surface acre was used. Fingerlings were counted at time of harvest and three days later to determine the comparative survival of the different harvesting techniques.

Principal Investigator: *S. Flickinger*

Discipline Involved: *Cooperative Fishery Unit*

Beginning Date: *4-1-70* Completion Date: *3-31-71*

Sponsor: *Colorado Division of Game, Fish and Parks*



Deer Study at Mesa Verde

## OBJECTIVES

To investigate the pertinent biology of the deer of Mesa Verde National Park, and of their range, which relate to proper management.

## APPROACH

Four phases were each planned as complete projects: distribution and movement, physiology and condition, population dynamics, and range condition and trend. They were coordinated by continual contact among the four graduate research assistants and two principal investigators. A two or three day visit each month involved the entire team in an effort to collect ten deer, necropsy them, and thus gain information on physiology and condition, reproductive status, age structure, and food habits. Deer were captured with drugs and marked for movement studies. Pellet plots measured deer populations and browse plots measured forage utilization.

Principal Investigator: *Harold W. Steinhoff*

Discipline Involved: *Wildlife Biology*

Beginning Date: *6-1-69* Completion Date: *8-31-70*

Sponsor: *U. S. Department of Interior*



## Prevention of Deer Starvation

### OBJECTIVES

To study effects of various dietary regimes on deer rumen function.

### APPROACH

A variety of diets with low, medium, and high protein and fiber contents are fed to groups of deer. Rumen samples are taken via stomach tube and contents analyzed. Rate of passage of ingesta is also investigated.

Principal Investigator: *J. Nagy*

Discipline Involved: *Wildlife Biology*

Beginning Date: *7-1-69* Completion Date: *6-30-71*

Sponsor: *State of Colorado*

## SOIL AND LAND RESOURCES



### Correlation of Economic and Physical Factors Affecting Selection of Land for Irrigation

#### OBJECTIVES

1. To obtain crop (corn, sugar beets, wheat) production response from irrigation in relation to nitrogen fertilizer levels on a specific soil, and to evaluate for correlation purposes the soil and climate variables influencing yield response.
2. To evaluate the economic relationship of the various cultural factors and production response in a statistically derived production function, which will be useful in future considerations concerning the selection of lands for irrigation development.

#### APPROACH

Field plots at Fort Collins and at Springfield have been established to evaluate yield response to nitrogen fertilizer treatments and irrigation levels based upon soil-water potential values. Yield values are obtained and soil and climatic characteristics are measured. The data generated are analyzed through economic and statistical models to derive the water-fertilizer-crop yield response relationships.

Principal Investigators: *R. E. Danielson, M. Skold, R. A. Young*

Disciplines Involved: *Agronomy, Economics*

Beginning Date: *5-1-68* Completion Date: *6-30-71*

Sponsor: *Iowa State University*



### Floristic Inventory of the Vegetational Resources of Colorado

#### OBJECTIVES

To develop and maintain the floristic inventory for Colorado. To structure this inventory so that it will serve both as a tool for basic research as well as providing valuable information which can be applied by land-use planners and resource managers. To provide access to the floristic inventory through a computerized information retrieval system.

## APPROACH

Develop a data bank based upon floristic information and provide access to this information with a computerized retrieval system. Information stored in herbaria will be used as the primary documentation for the data bank. The retrieval system will be structured to give output in the form of lists and maps which will allow correlations between plant distributions and a variety of natural and man-made features of the environment. Extend our knowledge of the floristic resources of the state through extensive field studies and active collection exchange programs with herbarium curators in bordering states.

Principal Investigators: *William M. Klein, Robert P. Adams*

Discipline Involved: *Botany*

Beginning Date: *7-1-70* Completion Date: *7-1-75*



Orchard Environmental Control

## OBJECTIVES

To evaluate commercial orchard heating systems for frost protection effectiveness. To develop techniques for effective frost protection in western Colorado. To develop low-temperature orchard management practices.

## APPROACH

Monitor leaf, bud, bark, and air temperatures throughout a tree subjected to influence of a heating system. Compare results with similarly instrumented control. Monitor wind velocity and relative humidity.

Experiment with combinations of heat and radiation insulation to obtain most effective protection methods.

Principal Investigators: *A. G. Story, C. R. Ure*

Disciplines Involved: *Agricultural Engineering, Horticulture*

Beginning Date: *7-1-69* Completion Date: *6-30-74*



## Effects of Intensive Grazing Management Systems on Sandhill Rangeland

### OBJECTIVES

To evaluate heavy continuous, moderate continuous, and heavy rotation systems of cattle summer grazing. To evaluate heavy year-round continuous grazing vs. four systems of year-round grazing rotations. To compare the morphological development of blue grama, sideoats grama, prairie sandreed, western wheatgrass, and needle-and-thread in relation to grazing treatment.

### APPROACH

Since 1955 moderate and heavy grazing intensities have been imposed on native sandhill range pastures each year from about May 1 to October 1. A 93-acre pasture will be divided into 31-acre units and utilized under a rotation management scheme at about the same stocking level as that utilized under the heavy continuous treatment to find a way to get comparable beef production without the expected decline in range condition. For comparison purposes the continuous grazing treatments will be continued as in the past. For the second objective, five 12-acre units will be used to test the effects of different management treatments where the grazing intensity is six acres per animal yearlong. Two steer calves weighing 300-400 pounds will be placed on each pasture treatment in November, and they will remain on that treatment until the following November when they will again be replaced with new weaned calves. For the third objective, weekly checks will be made on the major species in all treatments to ascertain if the developmental morphology is affected in any way. Also, a series of clipping treatments will be made at equally spaced time intervals. Other clipping treatments would be made by stage of development.

Principal Investigator: *B. E. Dahl*

Discipline Involved: *Range Science*

Beginning Date: *7-1-68* Completion Date: *6-30-73*



## Grazing Systems Utilizing Native Range, Seeded Grasses and Legumes, and Fertilization

### OBJECTIVES

To compare grazing systems and efficiency of forage utilization of native and seeded pastures under

fertilized and unfertilized conditions, and to compare effect of nitrogen fertilization and use of legumes on production and quality of seeded pastures.

## APPROACH

One of two unfertilized crested wheatgrass pastures will be grazed from May 1 to June 1, the other from May 1 to July 1. Another two similar pastures will receive nitrogen and phosphorus fertilization and will be grazed the same as the first two. Animals will be grazed on range until they are returned in September to use the regrowth. Pasture herbage production will be measured using clipping and water intake methods. Animals will be weighed on and off pastures. Records will be kept and analyzed for precipitation, maximum-minimum temperature, animal days grazing per pasture, daily water intake, and daily moisture percent in the forage. Representative forage samples and fecal samples will be collected periodically to evaluate the nutrient value and its relation to weight changes in steers. Four additional pastures will be seeded to crested wheatgrass-alfalfa mixture and worked into the above design.

Principal Investigator: *C. Terwilliger*

Discipline Involved: *Range Science*

Beginning Date: *7-1-68* Completion Date: *6-30-73*



Turf Investigations

## OBJECTIVES

1. To delineate problems in the establishment and management of turfgrass in Colorado.
2. To develop methods and equipment for sub-crown cultivation and chemical application.
3. To compare 100% sand and USGA green construction specifications.
4. To evaluate several species and varieties of grasses.

## APPROACH

Evaluate present practices of turfgrass establishment and maintenance. Compare timing and methods of soil cultivation under bluegrass sod for control of certain weeds and improvement of soil aeration. Determine the effectiveness of sand of specific particle size and shape in the root zone area for



reducing compaction under bentgrass and general turf responses under simulated golf course traffic conditions.

Principal Investigator: *William G. Macksam*

Discipline Involved: *Horticulture*

Beginning Date: *6-30-69* Completion Date: *6-30-73*



### Diseases of Turfgrasses

#### OBJECTIVES

To determine environmental effects on blight, footrot, brown patch, and snow mold in bluegrass and bentgrass. To study effects of fertilization, thatch removal, soil amendments, and chemicals on turf diseases.

#### APPROACH

Microenvironmental measurements will be made in bluegrass and bentgrass turf of air temperature, humidity, and soil moisture by means of thermographs and Bourdon gauges. The turf will be inoculated with various pathogens.

Comparisons of swept and non-swept turf areas will be made on golf courses to evaluate the turf disease syndrome.

The use of mist chambers and plastic covers will be used to develop better methods of artificially inciting turf diseases, particularly *Helminthosporium* and brown patch.

Principal Investigator: *Jack Altman*

Discipline Involved: *Botany*

Beginning Date: *7-1-68* Completion Date: *6-30-73*



### Evaluation of Timber-Supply Forecasting Methods--Stochastic Approaches

#### OBJECTIVES

To evaluate present systems of timber-supply projection and, if dictated by early results, to develop improved projection methods.

## APPROACH

Evaluation of present systems will be accomplished through use of Monte Carlo techniques, simulation, and comparison of results with actual data from repeated sampling. Stochastic techniques, primarily Markov chains, will be examined in attempts to develop improved projection systems.

Principal Investigator: *W. E. Frayer*

Discipline Involved: *Forest and Wood Sciences*

Beginning Date: *7-1-69* Completion Date: *6-30-72*



**Internal Water Stress and Establishment of Ponderosa Pine**

## OBJECTIVES

To determine normal pattern of internal water stress in pine seedlings and its relationship to transpiration, provenance, and cultural practices in natural and planted seedlings.

## APPROACH

Measure water stress in needles of planted and natural ponderosa pine seedlings with the Scholander pressure chamber at weekly intervals during the growing season. On selected days water stress and transpiration will be measured bi-hourly. Record growth and abiotic site factors. Analyze effects of provenance, site preparation, type of stock, and planting method.

Principal Investigator: *C. W. Barney*

Discipline Involved: *Forest and Wood Sciences*

Beginning Date: *7-1-70* Completion Date: *6-30-73*



**A Model for Multiple-Use Resource Decisions in the Ponderosa Pine Ecosystem**

## OBJECTIVES

To develop a model to relate timber, range, and wildlife resources of the ponderosa pine ecosystem in a multiple-use management system. To test the model with empirical data from a specific area of ponderosa pine having significant proportions of timber, range,

and wildlife resources. To obtain field data crucial to final testing and refinement of the model.

## APPROACH

A management unit of the landscape in the ponderosa pine ecosystem will be selected of a size and with natural boundaries which incorporate a multiple-use system that is as nearly as possible a closed system. A conceptual model will be constructed through a series of discussion sessions with a range biologist, systems analyst, wildlife biologist-economist and ecologist, forest economist, and resource data analyst. Segments of the model, or submodels, will include functions, subroutines, or expressions such as precipitation, temperature, wind, site factors, plant growth, plant competition, plant nutritional index, plant regeneration, plant harvest, animal growth and reproduction, and water yield. These submodels would include management decision options and their possible feedback on the system. The challenge will be to combine the resource knowledge and analytical insight of the participants into a model which can evolve to greater degrees of usefulness and realism rather than to be stymied by theoretical limitations. The model will be tested and refined with data from a specific geographic area, probably the Black Hills. Missing data and poorly known biologic systems will be identified for future studies.

Principal Investigator: *Harold W. Steinhoff*

Discipline Involved: *Fishery and Wildlife Biology*

Beginning Date: *7-1-70* Completion Date: *6-30-73*



**The Effect of Rainfall Acidity  
on Coniferous Trees**

## OBJECTIVES

1. To determine the tolerance levels of native coniferous species to artificially applied acid precipitation.
2. To determine the effects of artificially applied acid precipitation on the growth, vigor, and foliage characteristics of native coniferous seedlings.

## APPROACH

Three species of native coniferous species will be subjected to acid precipitation applied at two levels

of acidity plus a control. Tests will be done on plot basis with approximately three-year old seedlings as subjects. Seedlings will be examined by color, needle length, bud formation, shoot elongation, etc.

Principal Investigators: *W. E. Marlatt, W. D. Striffler*

Discipline Involved: *Watershed Sciences*

Beginning Date: *9-1-70* Completion Date: *6-30-72*



### **Climate and Phenological Patterns for Agriculture in the Western Region**

#### **OBJECTIVES**

To determine patterns and variability of climate. To associate phenological response with climatic data. To develop interpretations of phenological and climatic data for agricultural and other applications.

#### **APPROACH**

Examine various techniques of statistically describing and summarizing in a suitable publication format both precipitation and temperature durations. Update and expand tape weather data library to be used in future regional publications summarizing temperature, precipitation, and evaporation data. Establish additional phenological gardens for the study of periodic biological phenomena in relation to the environment.

Principal Investigators: *Dale F. Heermann,  
Eugene Siemer*

Disciplines Involved: *Agricultural Engineering,  
Agronomy*

Beginning Date: *7-1-67* Completion Date: *6-30-72*



### **Improving High Altitude Mountain Meadow Ranch Management Practices**

#### **OBJECTIVES**

To compare the economics of alternative ranch management systems. To determine the feasibility of introducing management system changes into the existing operations. To develop a pilot ranch.

## APPROACH

Four groups of 24 cows will be used to evaluate four management systems, which will vary from a minimum capital input to a high capital investment. System one (minimum input) follows usual practices of late cutting of hay with no fertilizer application, usual flood irrigation and no land leveling, grazing cows and calves on National Forest in the summer and sagebrush-grass ranges in the spring and fall, with winter feeding of low quality hay. System two involves application of 200 pounds nitrogen per acre on non-leveled hayland receiving intermittent irrigation, cattle grazing will be same as in system one; winter feeding will be with high quality hay. System three is the same as two except cows and calves will be on forest range only one month and then returned to graze meadow aftermath until winter feeding begins. System four involves leveling, reseeding, and fertilizing (200 pounds N per acre) with controlled irrigation, and keeping cattle yearlong on meadows (winter feeding of high quality hay). Each cow-group will consist of six commercial Herefords, six partially inbred Herefords, six Charolaise x Angus crossbreds, and six Brown Swiss, all bred to Hereford bulls. Biological and monetary data will be used for evaluating the systems.

Principal Investigator: *T. H. Hall*

Disciplines Involved: *Agronomy, Economics, Science*

Beginning Date: *7-1-66*      Completion Date: *6-30-71*



**Soil, Water, and Plant Investigations  
at High Elevations**

## OBJECTIVES

To study the soil, water, and plant resources of the mountain meadow as a means of obtaining greater efficiency in the production of forage.

## APPROACH

The integrated effects of the factors of soil fertility, climate, and plant development will be evaluated in terms of forage production at high elevation through laboratory, growth chamber, greenhouse, and field studies. The cycling and utilization of plant nutrients will be investigated, particularly carbon and nitrogen, to the end of producing a more

mobile soil fertility regime. Plant material improvement methods will include selection and hybridization, and plant management methods will include determining and manipulating progressive morphological, anatomical, and chemical development.

Principal Investigators: *E. G. Siemer, F. A. Norstadt*

Discipline Involved: *Agronomy*

Beginning Date: *3-1-51* Completion Date: *6-30-73*



### Classification of Complex Resource Systems

#### OBJECTIVES

To investigate techniques for identifying socially meaningful combinations of resource qualities of a region, for evaluating classification units for ecological validity, and for predicting effects of manipulation on resource classification units.

#### APPROACH

Association analysis; multivariate statistical analyses; gradient and ordination analyses; and systems and information analyses upon vegetation, soil, geological, climatological data sets. Resource data of reconnaissance and analytic sampling from Colorado, Oregon, New Mexico, and Utah. The basis of classification will be established numerical procedures applied to large data matrices.

Principal Investigator: *William H. Moir*

Discipline Involved: *Range Science*

Beginning Date: *7-1-69* Completion Date: *6-30-71*



### Terrain Model for Evaluating Aesthetics of Management Practices

#### OBJECTIVES

To provide a means by which a series of timber cutting alternatives may be simulated for a single landscape and their aesthetic impacts tested by the use of models.

#### APPROACH

A scale model will be built of an existing timbered area and designed to permit a photographic record to

be made of simulated changes in landscape appearance. Photographs will be made of field sites and compared to the model to determine the effectiveness of this method as a means of evaluating proposed changes in landscape appearance.

Principal Investigators: *Arthur T. Wilcox, Hubert D. Burke*

Discipline Involved: *Recreation Resources*

Beginning Date: *7-1-70* Completion Date: *6-30-71*



State Soil Survey and Characterization of Benchmark Soils

## OBJECTIVES

1. To secure an inventory of the soil and agricultural land resources of Colorado in cooperation with agencies participating in the National Soil Survey Program.
2. To characterize benchmark soils as to physical and chemical properties and their productivity with different systems of management under a specified environment.

## APPROACH

1. Cooperate with all agencies involved in the National Soil Survey Program by participating in preparation of soil survey work plans, field reviews, field correlations, and writing soil survey reports for publication.
2. Benchmark soils will be studied for the following kinds of data: soil laboratory analyses by soil type and phase; weather data, both on specific sites for which analytical data and recorded experience are available and on the range of climatic conditions in which the soil occurs, yield and management data by soil type and phase; and soil mechanics and other engineering data by soil type and phase.
3. Use the benchmark soil data as a basis for making predictions of behavior of all the other soils of the area and develop for immediate use the best interpretations that can be made on the basis of available knowledge and experience.

Principal Investigators: *A. J. Cline, E. M. Payne*

Discipline Involved: *Agronomy*

Beginning Date: *7-1-69* Completion Date: *6-30-73*



## Production Potential of Sagebrush Sites in Western Colorado

### OBJECTIVES

1. To determine the relationship between sagebrush plant communities, soil, geology, topographic location, and climatic conditions.
2. To define specific range sites within the study area.

### APPROACH

Vegetation data from 42 sample areas on Mancos shale and on the Brown park formation were collected. Physical and chemical analysis on soil samples taken from the same areas in 1969 were completed in the laboratory.

Principal Investigator: *C. Terwilliger*

Discipline Involved: *Range Science*

Beginning Date: *8-13-63* Completion Date: *12-31-70*

Sponsor: *U.S.D.I. - Bureau of Land Management*



## Chatfield Vegetation Management Plan

### OBJECTIVES

The objective of this management plan is to set forth recommendations, procedures, estimated costs, and sequence for the establishment of a permanent vegetative cover within the boundaries of the Chatfield Reservoir project, except for special areas which are detailed in the plan. Special emphasis is placed on establishing vegetation compatible with heavy outdoor recreation use consistent with the ecological composite of soil, climate, fauna, flora, and man. This plan is to be used as a guide by the forester for the establishment, improvement, and maintenance of the vegetative cover.

### APPROACH

Data and information for this plan was collected from the following sources: U. S. Geological Survey; Soil Conservation Services; Colorado Game, Fish and Parks; Denver Field Ornithologists; CSU Extension Agronomist; CSU Extension Range Specialist; CSU Range Department; CSU Extension Entomologist; CSU Extension Irrigation Specialist; U. S. Army



Corps of Engineers; U. S. Forest Service; and G. F. Kessler and Assoc., Inc.

Principal Investigator: *D. L. Brown*

Discipline Involved: *Forestry (Colorado State Forest Service)*

Beginning Date: *1-20-69* Completion Date: *4-1-71*

Sponsor: *U.S.D.A. - Forest Service*

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