

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 on inventory, development, marketing, and processing of natural resources has not been included.

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 Environmental Resources Center serves the faculty as an instrument of coordination for interdisciplinary research and serves those outside the University as a point of contact.


Director, Environmental
Resources Center

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AIR QUALITY



Ambient Ethylene and Oxidant Concentrations in the Denver Metropolitan Region

OBJECTIVES

To make a reasonable estimate of pollutant dosages actually present in a metropolitan region and to determine if, in fact, these dosages are sufficient to cause significant damage to economic plants.

APPROACH

Ambient air analyses are made at random intervals during periods of the year when high pollution incidence may be expected; or records from the State Department of Public Health and the Denver Air Pollution Division are examined—depending upon the pollutant. The results are plotted in order that the time-concentration dosage may be determined. Frequency histograms are constructed in order to arrive at an estimation of occurrence of the dosages. From these estimations, the data is compared with results obtained from actual treatment of selected plant material at the research station.

Principal Investigator: **Joe J. Hanan**

Discipline Involved: **Horticulture**



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 is used to reduce particulate and SO₂ 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**

Sponsor: **HEW - NAPCA**



Effects of Air Pollutants on Economic Plants

OBJECTIVES

1. To determine the effects, singly and in combination with each other, of ethylene, ozone, and SO₂ on marketability of cut flowers.
2. To determine the chronic effect of low dosages of selected air pollutants on plant growth and yield.

APPROACH

In both objectives, the procedure is to expose plant material to varying concentrations of air pollutants for different time periods. The time of exposure and concentrations will be evaluated in terms of dosages (ppb-hrs) and that dosage's effect on growth. The results will be correlated with ambient air analyses in the Denver region to arrive at an estimation of damage and feasible practices to alleviate that damage.

Principal Investigator: **Joe J. Hanan**

Discipline Involved: **Horticulture**



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**

Sponsor: **AEC**



**Particulate and Gas Diffusion
in the Lower Atmosphere**

OBJECTIVES

To develop adequate methods of measuring pollutant concentrations to aid in the development of surveillance methods for pollutant concentration and dispersion.

APPROACH

Research effort is concentrated on predicting pollutant diffusion by appropriate and accessible velocity measurements. A field station consisting of a fan 10 feet in diameter is used to generate a controlled flow field.

Principal Investigator: **W. Z. Sadeh**

Discipline Involved: **Civil Engineering**

Sponsor: **NASA**



Properties of Particulate Pollutants

OBJECTIVES

These studies should indicate the magnitude of finely divided solids acting as carriers for the transport of gaseous pollutants to the lungs and the desorption rates at the temperatures and humidities likely to be encountered in the lung.

APPROACH

Determine physical adsorption isotherms of gaseous pollutants from:

1. Pure sulphur dioxide systems at pressures corresponding to the partial pressures in air at the ppm level as a function of temperature.
2. Air containing sulphur dioxide at the ppm level as a function of temperature and humidity.

Principal Investigator: **M. L. Corrin**

Discipline Involved: **Atmospheric Science**

Sponsor: **EPA**



**A Research and Development Technique for
Estimating Atmospheric Dispersion**

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**

Sponsor: **Bureau of Reclamation**

ENGINEERING WORKS



Cavitation Scale Effects

OBJECTIVES

Evaluation of cavitation scale effects on simplified orifice shapes in pipeline flow were investigated. It was of interest to evaluate how incipient cavitation conditions change with a variation in pressure or velocity and the change in size of the test component.

APPROACH

Flat plate orifices were fabricated in various shapes which resembled the general flow pattern through some of the more common types of valves. These plates were fabricated in sizes to fit in pipes of from 1 inch to 24 inches in diameter. The orifices were then installed in the pipelines and flow tested under a variety of flow conditions to evaluate the incipient cavitations and scale effects.

Principal Investigator: **J. Tullis**

Discipline Involved: **Civil Engineering**

Sponsor: **NSF**



Fluxes of Heat, Momentum and Tracers in Wind and Water Tunnels

OBJECTIVES

To develop a single mathematical model which will enable prediction of concentrations of particulate matter in the air, at the surface, and in water downstream from a source. An experimental effort is proposed in which the same tracer in the air, at the surface, and in water be used to verify the numerical models.

APPROACH

Research on the movement of tracers in the turbulent boundary layer above the air-water interface, on the surface, and in the water has continued from 1968 to the present in the wind and water tunnels in the Fluid Dynamics and Diffusion Laboratory. The results of these studies should lead to three mathematical models describing each of the problems. These are to be integrated into a single mathematical model.

Principal Investigator: **J. Gessler**

Discipline Involved: **Civil Engineering**

Sponsor: **AEC**



Model Study

Rommel Dam – Arkansas Light & Power

OBJECTIVES

Develop design of plunge pool to protect dam from floods overtopping it.

APPROACH

Hydraulic model studies on fixed contract price.

Principal Investigator: **J. Ball**

Discipline Involved: **Civil Engineering**

Sponsor: **Fargo Engineering Company**



Tarbela Dam Model Study--1:24 Service Gates

OBJECTIVES

To determine hydrodynamic forces on large fixed wheel gates for the Tarbela Project in West Pakistan--measure local pressures at various points on the gate to determine pressure distributions--calculation of forces and vibrations to determine design adequacy. Also measure pressures in gate structure and flow coefficients for the gate.

APPROACH

Experimental--two model scales are being used, 1:70 (model-to-prototype) and 1:24.

Principal Investigator: **S. Karaki**

Discipline Involved: **Civil Engineering**

Sponsor: **Tippets-Abbott-McCarthy-Stratton**

ENVIRONMENTAL CONTAMINANTS



Analytical Pulse Polarography

OBJECTIVES

1. To study methodology of pulse polarography for application to trace analysis.
2. To develop analytical techniques for practical procedures aimed at trace analysis in water and other systems.

APPROACH

Commercial and computerized instrumentation are used to carry out electrochemical experimentation.

Principal Investigators: **R. A. Osteryoung, J. G. Osteryoung**

Discipline Involved: **Chemistry**

Sponsor: **NSF**



Apple Insect and Mite Population Management in the Orchard Ecosystem

OBJECTIVES

1. To evaluate and compare by computer analysis the insecticide spray records of apple growers and the pesticide efficiency of pheromone traps.
2. To increase the efficiency of orchardists by developing a computerized approach to apple production.

APPROACH

The large-scale utilization of the synthetic pheromone traps provides the means for minimizing both the amount of pesticide contamination in the environment and shifting insect control back to biological approaches.

The Zoecon Corporation will supply a large quantity of traps which will be mailed weekly to apple growers in Colorado, New Mexico, and Utah. The traps will be returned at the end of each week to Extension Service project leaders for weekly counts of codling moths, mites, and beneficial species. A computer analysis will be made with the data.

Principal Investigators: **J. A. Quist, Colorado; J. Durkin, New Mexico; J. Barlow, Utah**

Discipline Involved: **Entomology**

Sponsor: **Four Corners Regional Commission**



Availability and Chemical Behavior of Phosphate Fertilizers in Saline and Sodium Soils

OBJECTIVES

1. To determine the effect of soluble salts and/or exchangeable sodium on the availability of phosphorus to plants.
2. To determine the influence of soluble salts and/or exchangeable sodium on the chemical reaction of phosphate fertilizer with soil.

APPROACH

Greenhouse experiments will be conducted with alfalfa, small grain, or sugar beets in saline and/or sodium soils selected from various areas in the state. The crop will be harvested for yield and plant analysis. Phosphorus availability evaluated in terms of dry matter production and phosphorus uptake will be related to soil properties determined in the laboratory. Laboratory kinetic studies will be conducted to study the reaction of phosphate fertilizer materials with saline and sodic soils.

Principal Investigator: **W. R. Schmehl**

Discipline Involved: **Agronomy**

Sponsor: **CSU Experiment Station**



Base Line Study of Mercury in the Environment

OBJECTIVES

To make comparisons in levels of mercury between pre-industrial revolution periods and the present time.

APPROACH

The base line of mercury 250 years ago will be determined through the study of bat guano in caves in southwestern United States. These dry caves maintain constant temperature and humidity. The colonial bats that inhabit the caves are migratory, living in the caves from April to October. A beetle population lives on the floor of the cave on excrement and fallen bats, reducing the surface of the guano to powder in contrast to the coarser subsurface. Over the centuries the guano has built up in stratified layers. Bats feed on moths and insects that have absorbed mercury over the centuries. Cores will be taken of the stratified guano and analyses made of the chemical content that was deposited back in time. This will provide a study of mercury in profile.

Principal Investigator: **M. Petit**

Discipline Involved: **Microbiology**

Sponsor: **Rockefeller Foundation**

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 the 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 Investigator: **R. M. Hansen**

Discipline Involved: **Range Science**

Sponsor: **CSU Experiment Station**



Disposition and Possible Environmental Impact of Silver Iodide from Convective Cloud Seeding for Hail Suppression

OBJECTIVES

To study the disposition and environmental impact of silver iodide on vegetation, organic matter, soil, stream sediment, and water following cloud seeding in hail suppression operations.

APPROACH

The hail suppression target area is monitored before seeding commences each summer, after each seeding event, and at the end of the seeding season. Silver uptake by major forage and crop species is studied in the greenhouse. The environmental effects of varying silver concentrations and sources are studied on both soil and aquatic microorganisms. Movement and possible concentrations of silver in the food chain will be investigated.

Principal Investigators: **H. L. Teller, D. A. Klein**

Disciplines Involved: **Watershed Science, Microbiology**

Sponsor: **National Center for Atmospheric Research**



Disposition and Possible Environmental Impact of Silver Iodide from Orographic Cloud Seeding

OBJECTIVES

1. To monitor levels of silver on the San Juan target area of the upper Colorado River Basin Project following cloud seeding operations.
2. To study the movement of silver through soil cores in the laboratory.
3. To carry out pilot studies on silver distribution and accumulation around generator sites.
4. To study the uptake of silver iodide by plants.
5. To determine the environmental impact of silver iodide on soil microorganisms, both in field samples and under controlled laboratory conditions.

APPROACH

Samples of soil, litter, and vegetation are collected twice a year at selected sites in spruce, aspen, and grass communities on the target area. Undisturbed soil cores are leached with silver solutions of varying concentrations and subsequently analyzed for silver through the profile. Generator sites are sampled for silver accumulation. Soil respiration and other tests are carried out with varying concentrations and sources of silver on field samples from the target area, samples from treated plots, and on laboratory cultures.

Principal Investigator: **H. L. Teller**

Disciplines Involved: **Watershed Science, Microbiology**

Sponsor: **Bureau of Reclamation**



Economic and Social Impact of Adjustment In Use of Chemicals in Agriculture

OBJECTIVES

To assess socio-economic values and assign internal and external cost factors relating to the effects of the use of agricultural chemicals and to their effects in the environment.

APPROACH

A comparative analysis of the economic, political, and legal techniques of agricultural chemical control will be made. New models will be examined and tested against current data.

Principal Investigators: **D. Seckler, G. Radosevich, L. Hartman**

Discipline Involved: **Economics**

Sponsor: **CSU Experiment Station**



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 3-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**

Sponsor: **CSU Experiment Station**



Effects of Silver Iodide Complexes upon Animal Digestive Systems

OBJECTIVES

To determine the concentration of silver iodide which would have an adverse effect upon rumen and cecum microorganisms present in animals' digestive tracts.

APPROACH

An experimental study will be made of 12 goats, nine of which will be fistulated and separated into three groups, one of which will be a control group. Varying concentrations of silver iodide will also be added to the diets of rabbits.

Principal Investigator: **J. Bailey**

Discipline Involved: **Fishery and Wildlife Biology**

Sponsor: **Bureau of Reclamation**



Environmental Improvement Through Biological Control and Pest Management

OBJECTIVES

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

APPROACH

1. Test artificial food sprays to concentrate aphid predators in alfalfa.
2. Importation and release of new biotypes of *bathyplectes curculionis*.
3. Studies of the life history and importance of secondary parasites of *B. curculionis*.
4. Evaluation of new insecticides for control of alfalfa pests.

Principal Investigator: **R. G. Simpson**

Discipline Involved: **Entomology**

Sponsor: **CSU Experiment Station**



Gall Insects of Pinon Pine

OBJECTIVES

1. To determine the biology and distribution of all midges attacking pinon pine.

2. To develop chemical and biological control measures for these posts.

APPROACH

1. The biology of two gall midges, *Janetiella coloradensis* and *Pinonia edulicela* have been studied in the field and in the laboratory. Artificial infestations of the spindle gall midge were established to make detailed observations possible. Distribution studies were conducted in various pinon stands where observations and collections were made.
2. Chemical control tests were established for both galls at several sites in Fort Collins and Denver.

Principal Investigator: **W. Brewer**

Discipline Involved: **Entomology**

Sponsor: **CSU Experiment Station**



Impact on Man of Environmental Contamination Caused by Lead

OBJECTIVES

Generate and evaluate information which will make it possible to assess the impact on man of environmental contamination caused by lead. An attempt will be made to develop a model useful for predicting the nature and range of lead fallout.

APPROACH

City corridor-ventilation conditions conducive to hazardous build-up of airborne lead will be studied and possible inadvertent weather modification caused by lead will be examined. Pathways for travel of lead fallout to man will be explored by studying the history of lead in the soil and subsequent accumulation in selected plant and animal species. The economic consequences of environmental lead contamination will be examined in terms of costs and benefits. As study continues, increasing emphasis will be placed on understanding ecological and economic consequences of lead contamination.

Principal Investigator: **H. Edwards**

Disciplines Involved: **Mechanical Engineering, Atmospheric Science, Economics, Chemistry, Zoology, Botany and Plant Pathology**

Sponsor: **NSF**



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**

Sponsor: **CSU Experiment Station**



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 Investigator: R. E. Johnsen

Discipline Involved: Entomology

Sponsor: CSU Experiment Station



Response of Plants and Plant Communities to Sustained Use of Herbicides

OBJECTIVES

To determine effects of repetitive application or pollutional 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

Sponsor: CSU Experiment Station



Sedimentation of Particulate Air Pollutants

OBJECTIVES

To compare with the source the relative proportion of dustfall attributed to man-made pollutants. A comparison will be made between city and countryside. The particle size distribution of sedimentation will also be determined.

APPROACH

Pollutants will be identified through morphological and other microscopic techniques. Particle size of the ambient air will also be studied through use of an impactor or membrane filter device. An electron microscope will be used to detect sub-micron particles.

Principal Investigator: H. Riehl

Discipline Involved: Atmospheric Science

Sponsor: NSF



Trace Metal Pollution from Electric Power Generating Activities

OBJECTIVES

The objectives of the research are to measure trace elements in the environment of an existing power generating plant and to compare these data with similar measurements made in control areas which have not been subjected to modification by industrial activities. From the basic data, a prediction model will be designed so that if additional electric power generating sources are installed, one can then project any possible trace metal pollution which might result from the activities of that plant.

APPROACH

Samples of water, soil, vegetation, and animals from the vicinity of an existing electric power generating plant are collected, prepared for analysis, and the amounts of various trace metals estimated using the atomic adsorption spectrophotometer. The metals of great concern at the moment are lead, mercury, zinc, cadmium, and beryllium. From time to time, chromium and manganese are also studied.

Principal Investigator: C. G. Wilber

Discipline Involved: Zoology

Sponsor: CSU Department of Zoology



Wind Tunnel Model Study of the Dow Chemical Company at Rocky Flats

OBJECTIVES

To determine the dispersal and trajectories of potential effluents from the Dow Flats facility.

APPROACH

A scale model of the plant and local terrain will be placed in a wind tunnel capable of simulating atmospheric conditions. The data to be obtained include:

1. Mean wind speed and temperature in the air stream approaching the model.
2. Turbulence intensities in the approaching air stream.
3. Flow patterns over and immediately downstream from the structures.
4. Ground contact of leaking plumes.
5. Concentration downstream of the stack.

Principal Investigator: R. N. Meroney

Discipline Involved: Civil Engineering

Sponsor: Dow Chemical Company

ENVIRONMENTAL HEALTH



Alaskan Radiation Ecology Study

OBJECTIVES

To examine in greater detail the 11 years of data of radionuclide cycling (especially ^{90}Sr and ^{137}Cs) within northern Alaskan ecosystems during the period 1960-1970, to extract the maximum information from the studies and to provide a single synthesis of the study.

APPROACH

Radionuclides other than ^{90}Sr and ^{137}Cs , such as ^{54}Mn , ^{65}Zn , $^{95}\text{Zr-Nb}$, ^{106}Ru , and ^{144}Ce , and the stable elements ^{39}K and ^{40}Ca will receive greater attention than before. Additional analyses of ^{90}Sr and ^{137}Cs data will be made in various components of the food chain, especially the fairly extensive series of carnivore samples (wolves, wolverines, and foxes) obtained at Anaktuvuk Pass and lichen samples obtained from some 15 northern locations other than the control site at Anaktuvuk Pass. Anthropological information contained in a continuous personal journal during the period 1960-1971 will be extracted and related to radionuclide studies involving the people, especially at Anaktuvuk Pass.

Principal Investigators: **W. C. Hanson, F. W. Whicker**

Discipline Involved: **Radiology and Radiation Biology**

Sponsor: **AEC**



Antibiotic Resistance to Salmonella Outbreaks

OBJECTIVES

To determine if the nonmedical use of antibiotics and the resistant organisms create health problems, particularly in the treatment of diseases involving the gastrointestinal tract.

APPROACH

Calves will be treated with penicillin-streptomycin before shipment to the feedlot. Records will be kept of calves' health, treatments, and therapy. Laboratory analyses will be made throughout the study of fecal specimens, pathogenic specimens from barns, feeding buckets, and other areas that come in contact with the calves.

Principal Investigator: **L. P. Williams**

Discipline Involved: **Microbiology**

Sponsor: **USDA Food and Drug Administration**



Environmental Radiation Surveillance-- Fort St. Vrain

OBJECTIVES

To design and conduct an environmental radiation surveillance program in the vicinity of the Fort St. Vrain Nuclear Generating Station.

APPROACH

The critical nuclides to be released and the critical pathways to man were analyzed. A surveillance program was designed to detect any radiation exposures to the public and any significant environmental effects that could result from radioactivity releases from the plant.

Principal Investigator: **K. Schiager**

Discipline Involved: **Radiology and Radiation Biology**

Sponsor: **Public Service Company**



Establishment of Institute of Rural Environmental Health

OBJECTIVES

To improve the health, safety, and well-being of residents in Colorado and the Rocky Mountain region, especially those engaged in agriculture, by the application of preventative medicine through research, education, and service.

APPROACH

The College of Veterinary Medicine and Biomedical Sciences is responsible for the institute. An advisory panel consisting of the program and associate directors and additional members will guide the institute. Initially, two sections will be formed: chemical epidemiology and zoonotic ecology-comparative medicine. After gathering data during Phase I and II, a formal program of services to professional and lay interest groups should be available. This program may include seminars, workshops or training courses, and the preparation and dissemination of written and audio-visual materials on wide spectrums of rural health hazards and their prevention.

Principal Investigator: **J. R. Bagby**

Discipline Involved: **Microbiology**

Sponsor: **Kellogg Foundation**



Metabolism in Ruminants of $^{210}\text{PoO}_2$

OBJECTIVES

To estimate the hazard to man from accidental environmental contamination of ^{210}Po . It was hypothesized that the major route to man of such contamination is the plant-cow-milk food chain. We attempted to quantitate the transfer at each one of these steps.

APPROACH

The transfer from plants to ruminants was investigated by growing plants in high activity contaminated soil and feeding this to goats. The kinetics of transfer from goats and cows to milk was investigated by observing milk, urine, and fecal concentrations following single oral doses. The metabolism of Se and S, elements in the same chemical group, was compared to that of Po.

Principal Investigators: J. Johnson, R. L. Watters

Disciplines Involved: Radiology and Radiation Biology, Animal Science

Sponsor: AEC



Plutonium in the Rocky Flats Environs

OBJECTIVES

To identify and quantify any biological pathways for movement of plutonium in the three major water courses of Rocky Flats. There have been no studies previously reported in the literature for freshwater systems.

APPROACH

Samples of water, sediment, aquatic plants and animals were collected from March 1, 1971 and assayed for plutonium content. The species and seasonal abundances of the plant and animal life were inventoried concurrently.

Principal Investigators: J. E. Johnson, R. L. Watters

Disciplines Involved: Radiology and Radiation Biology, Animal Science

Sponsor: Dow Chemical Company



A Program for Improving Underground Construction-Phase I

OBJECTIVES

1. To develop social indicators for assessing the social impact of underground life. To determine at what stage people become impervious to their environment.
2. To determine the social and economic benefits accruing from the transfer of civil works functions to subsurface space.

APPROACH

Social indicators will be applied to particular situations to determine cost-benefit ratios. In this Phase I period, areas of needed information will be identified with respect to their effects on human beings physically and psychologically.

Principal Investigator: D. W. Hill

Discipline Involved: Political Science

Sponsors: NSF and the American Society of Civil Engineers, Underground Construction Research Council



Radioecology of Natural Organisms

OBJECTIVES

To determine the behavior of radionuclides in, and the effect of radiation on, selected organisms and natural ecosystems in northcentral Colorado.

APPROACH

Strontium and calcium metabolism is being investigated in captive mule deer by dosing the animals with ^{85}Sr , ^{90}Sr , and ^{45}Ca and making subsequent whole body counts. The effects of radiation on pikes (*Ochotona princeps*) are being investigated in captive colonies in which the degree of intra-specific competition can be varied. An 8,750 curie ^{137}Cs source is being used to irradiate the natural grassland ecosystem. Structure of the plant community, distribution of arthropods, and soil microorganisms are under investigation in the radiation field. Food webs of selected grassland arthropods are being determined with ^{32}P . The kinetic behavior of cesium is being measured in a montane lake. Trout and other environmental samples are collected from mountain lakes throughout Colorado for ^{137}Cs , ^{90}Sr , Fb,

and Hg determinations. The terrestrial ecology of plutonium is under investigation at the Rocky Flats plant near Boulder, Colorado.

Principal Investigator: **F. W. Whicker**

Discipline Involved: **Radiology and Radiation Biology**

Sponsor: **AEC**



Radon Daughter Products Inhalation Study

OBJECTIVES

1. To investigate the physical characteristics of radon progeny aerosols in uranium mine atmospheres with respect to their depositions in the human respiratory tract.
2. To investigate field methods for measuring and evaluating the inhalation exposures of uranium miners.
3. To evaluate methods for controlling the inhalation exposures to uranium miners.

APPROACH

Extensive measurements of radon and radon progeny aerosols have been made in several uranium mines in Colorado and New Mexico. The measurements included concentrations of the individual nuclides, diffusion coefficients for each nuclide to be related to particle sizes, concentrations of condensation nuclei, fraction of particles carrying an electrical charge, barometric pressure, temperature, relative humidity, and ventilation rates. Measurements of radioactive aerosols deposited in the respiratory tract are made by external gamma-ray counting. Such measurements have been conducted on working uranium miners and on volunteer experimental subjects.

Principal Investigator: **Keith J. Schiager**

Discipline Involved: **Radiology and Radiation Biology**

Sponsor: **AEC**



Radon Progeny Exposure Control in Buildings

OBJECTIVES

To investigate methods for reducing or eliminating radon diffusion in buildings from uranium mill tailings (wastes) used as fill under and around foundations. For each method

tested, the objective is to determine degree of effectiveness and relative cost application.

APPROACH

Six experimental buildings were constructed on the CSU Foothills campus. The buildings were arranged in three pairs representing three typical types of construction: full basement, crawl space, and slab on grade. Uranium mill tailings were used under one building of each pair in a manner similar to the manner in which tailings have been used in uranium mill towns. The other building of each pair has no tailings and serves as a reference facility for determining natural background radiation. Control methods are applied to both buildings in a pair to determine the effectiveness.

Principal Investigators: **K. Schiager, H. G. Olson**

Disciplines Involved: **Radiology and Radiation Biology, Mechanical Engineering**

Sponsor: **EPA**



Retention of Fallout by Crops

OBJECTIVES

To determine the initial retention and retention as a function of time of simulated near-in fallout particles. The retention on agricultural crops and on livestock was necessary for radiation dose calculations from near-in fallout.

APPROACH

Sand was labeled with ^{177}Lu and used in particle size ranges 88-175 m and 175-350 m. It was spread by a blower over standing crops and livestock. Initial retention and retention versus time was determined by gamma-ray spectroscopy. The effect of mass loading and surface moisture was determined in a test aerosol chamber.

Principal Investigator: **J. E. Johnson**

Discipline Involved: **Animal Science**

Sponsor: **U.S. Army Office of Civil Defense**

ENVIRONMENTAL IMPACT



Carbohydrate Budget in Range Plants with Respect to Phenological Development and Defoliation

OBJECTIVES

To determine the balance of carbohydrate reserves in major range species with respect to their phenological stage of development and how various defoliation treatments affect the balance of carbohydrate reserves.

APPROACH

Plant samples for eight important range species have been collected and will be analyzed for carbohydrate reserves. These samples were taken from native plants that were unmolested and plants which had been defoliated at various frequencies and seasons of the year. These data should be useful in providing guidelines for the design of grazing management systems that will provide sustained production of important range forage species.

Principal Investigator: **M. J. Trlica**

Discipline Involved: **Range Science**

Sponsor: **CSU Experiment Station**



Classification of Complex Natural Resource Systems

OBJECTIVES

To develop techniques useful in classifying vegetation and soil characteristics of forested areas which would be useful in management of those areas.

APPROACH

The use of Shannon's information index has been employed to develop a mathematical model for classifying vegetation. This index has been modified to allow for various alternatives to vegetation classification. These alternatives include ecological, economical, and sociological values placed on vegetation.

Principal Investigator: **Charles D. Bonham**

Discipline Involved: **Forestry and Range Science**

Sponsor: **CSU Experiment Station**



Colorado Environmental Data System

OBJECTIVES

The objective of this project is the development of data systems for incorporation of environmental concerns into decision making by state, country, and community decision makers.

APPROACH

The procedures involved answering five questions, and then developing a data base given the answers to these questions. They were:

1. What kind of decisions (by public agencies) have significant environmental impacts?
2. What is the nature of the environmental impact that actions from these decisions are likely to generate?
3. What kind of information is necessary to guide decisions to assure that environmental impacts can be incorporated into the decision-making process?
4. What methods would be used to inventory this information?
5. What arrangements (institutions, etc.) are needed to increase the chance that the information inventoried is utilized in decision making?

Principal Investigator: **R. S. Whaley**

Discipline Involved: **Recreation Resources**

Sponsor: **Colorado Department Natural Resources**



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-foot by 50-foot 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, and hydrographs. Sediment samples will be collected for analysis.

Principal Investigator: **S. Schumm**

Discipline Involved: **Geology**

Sponsor: **U.S. Army Research Office**



Dynamic Inventory of the Mammals, Reptiles and Amphibians at the Fort St. Vrain Nuclear Power Plant Site

OBJECTIVES

1. Studies prior to nuclear activation to approximate base line values of ecological parameters in the terrestrial faunal communities. Documentation of existing population structure, population densities, species distribution, and species diversity of mammals, reptiles, and amphibians.
2. Temporal studies to identify seasons of the year when the terrestrial communities are most fragile and responsive to environmental change.
3. Continued studies after the nuclear power plant is activated to estimate the effects of the operations on the environment and the resultant impact on the terrestrial fauna. This information will be important in the selection of future power plant sites and operations which will minimize disturbance while maximizing beneficial aspects.

APPROACH

Delineate three or four different habitats. Faunal community structure should vary with habitat type. Plan to investigate the effect of distance from the power plant by delineating two or three concentric zones around the plant and sampling habitats within each zone. Also, sampling will be conducted as a function of time by dividing the year into four seasons.

Principal Investigators: **N. Lehner, B. A. Wunder**

Discipline Involved: **Zoology**

Sponsor: **Thorne Ecological Institute**



Ecological Data Storage Retrieval System for The Research Ranch

OBJECTIVES

To develop a computerized storage-information-retrieval system for ecological data describing The Research Ranch at Elgin, Arizona.

APPROACH

Vegetation and soils data will be described by sampling quadrats over the entire 7800-acre area. A storage-information-retrieval system will be formulated to contain this data and will be applicable on the CDC-6400 computer system at Colorado State University.

Principal Investigator: **Charles D. Bonham**

Disciplines Involved: **Range Science, Plant Ecology**

Sponsor: **The Research Ranch**



Effect of Clear-Cutting on Nutrient Cycling in Lodgepole Pine Forests

OBJECTIVES

For a number of reasons, including control of mountain pine, beetle damage, and dwarf mistletoe infections, lodgepole pine is almost always clear-cut. In this study specific nutrient compartments will be examined in clear cut areas.

APPROACH

Interdepartmental investigations will be made of the variability of mineral nutrients that are found in: 1) available soil nutrients, 2) vegetation, 3) forest floor humus, 4) water output, and 5) precipitation input.

Principal Investigator: **C. P. P. Reid**

Discipline Involved: **Forest and Wood Science**

Sponsor: **Rocky Mountain Forest and Range Experiment Station**



Environmental Effects on Aerospace Sensor Systems

OBJECTIVES

1. To develop models of natural and man-made environments.
2. To conduct extensive research into new types of sensors.
3. To improve sensor data interpretation in conjunction with overall sensor system optimization and a merging of our environmental, sensor, and systems analysis capabilities into a sensor system technology research group.

APPROACH

A multi-disciplinary research program is in progress in the areas of: re-entry plasmas, physical properties of ionospheric plasmas, optical and millimeter sensors, electromagnetic remote sensing, signal design and processing, and sensor system analysis.

Principal Investigator: **R. J. Churchill**

Discipline Involved: **Electrical Engineering**

Sponsor: **Department of Air Force**



Environmental Inventory--Piceance Basin

OBJECTIVES

To identify environmental elements occurring in Piceance Basin with special attention to those subject to change due to oil shale operations.

APPROACH

An eight-man interdisciplinary team was organized to make the inventory.

Principal Investigator: **N. A. Evans**

Discipline Involved: **Environmental Resources Center
Interdisciplinary**

Sponsor: **Cameron Engineers Company**



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**

Sponsor: **CSU Experiment Station**



Evaluation of Grazing Systems

OBJECTIVES

To evaluate the ecological changes in vegetation with respect to various grazing systems used by livestock.

APPROACH

Data which have been collected from various experiment stations in Colorado will be used to determine ecological changes occurring with respect to various grazing systems. Fifteen to twenty years of data on vegetation soil characteristics under various grazing systems are available for such an analysis.

Principal Investigator: **Charles D. Bonham**

Discipline Involved: **Range Science**

Sponsor: **CSU Experiment Station**



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**

Sponsor: **CSU Experiment Station**



Geomorphology of Valley Floors

OBJECTIVES

To determine the manner in which incision of a river channel into bedrock occurs. To determine the configuration of the newly formed bedrock surface. To determine if concentrations of heavy minerals can be expected to occur in systematic patterns on the floor of alluvial valleys.

APPROACH

A cohesive mixture of fine sand, silt, and kaolinite was placed in the 4 feet wide and 60 feet long A.R.S. flume at the Engineering Research Center. A small channel is cut in the surface of this material, and a controlled discharge of about 0.1 cfs is introduced into the channel. An incision of the channel occurs, the erosional changes are documented by photographs and precise measurements of channel dimensions.

Principal Investigator: **S. Schumm**

Discipline Involved: **Geology**

Sponsor: **NSF**



Grassland Biome--U.S. International Biological Program

OBJECTIVES

The overall purpose of the International Biological Program (IBP) is to examine "the biological basis of productivity in human welfare." The Grassland Biome is one of six biome studies being conducted in the United States and is part of an international effort to study grassland ecosystems. The understanding of the biological basis of productivity in nature requires also the understanding of an ecosystem. The Grassland Biome is conducting studies of various grassland types in the western United States. Intensive studies are being conducted at eight other grassland sites ranging from Oklahoma to Washington. Because of the complexity of ecosystems, and because of the skills and understanding required, these studies call upon the skills and knowledge of approximately 100 scientists at CSU and other universities.

APPROACH

To gain an understanding of the grassland ecosystems, research is underway to understand the interaction between

the abiotic, producer, consumer, and decomposer segments of the ecosystem. This involves field measurements to get time series sets of uniform data on the components of these system segments, of the climate, and field and laboratory rate process studies to determine the flows between the various system components. Through biological integration of these areas and through a systems analysis approach, such understandings are being quantitatively committed to mathematical models which can be used in a predictive sense to both understand and manage grassland areas.

Principal Investigator: **George M. Van Dyne**

Disciplines Involved: **Watershed Science, Range Science, Entomology, Agronomy, Cooperative Wildlife, Radiation and Radiation Biology, Botany and Plant Pathology, Microbiology, Atmospheric Science, Fish and Wildlife Biology, Zoology, Engineering, Chemistry, Mathematics, Animal Science**

Sponsor: **NSF**



Grazing Systems for Shortgrass Prairie

OBJECTIVES

To increase the biological efficiency of native shortgrass ranges through methods of grazing to provide optimum vigor of forage plants.

APPROACH

Abandoned go-back, seeded farm land, and native pastures are grazed in a rest-rotation system whereby one-third of the area in each type is rested each year. This system is compared to continuous grazing which is common practice.

Principal Investigator: **C. Wayne Cook**

Discipline Involved: **Range Science**

Sponsor: **CSU Experiment Station**



Identification of Urban Watershed Units Use

OBJECTIVES

To determine the impact of remote, multispectral sensing on urban watershed water yield predictive models.

Specifically: To develop a method whereby the important hydrologic units in an urban watershed on an areal basis can be spectrally separated.

APPROACH

Extensive air-photo analysis is used to determine the areally important hydrologic units in 16 Denver urban watersheds under detailed study for water yield by the USGS, Water Resources Division. The 30-year transition of these watersheds from natural land to urbanized use is interpreted from five to seven sets of historical aerial photographs yielding curves of the rates of urbanization. A series of spectroreflectance curves have been collected for 11 surface material classes found to be areally important in these watersheds, e.g., lawns, dirt, roads, concrete, etc. The best combination of two spectral bands was computed and tested using a multiband camera. Processing of the resulting images yields an areal separation of the urban watershed into its most important hydrologic units. The four bands to be used in the forthcoming Earth Resources Technology Satellite are also being tested.

Principal Investigator: **Lee Miller**

Discipline Involved: **Watershed Science**

Sponsors: **OWRR, NASA, NSF**



Management of Environmental Quality on Forested Land

OBJECTIVES

To develop environmental data bases and socio-economic impact analyses.

APPROACH

The environmental data base effort has yielded a raw data base which includes things such as soils, vegetation or ecotypes, topography, etc. Environmental impact descriptions written in terms of the raw data base are coupled with the data base to yield an environmental impact prediction system. The concepts are now being adapted to a computerized storage retrieval and display system. When this task is completed, hypotheses formulated without environmentally sensitive landscapes will be tested, e.g., is aspect correlated with erosion and will vegetation alone allow impact prediction?

The second effort looks at the impact of public land management on the viability of mountain communities. These analyses have taken two directions: 1) demographic analysis; and 2) the traditional economic impact analysis.

The considerations to date have been limited to management policy, but recreation, water, etc. policy will also be examined.

Principal Investigators: **R. S. Whaley, A. A. Dyer**

Discipline Involved: **Forest and Wood Science**

Sponsor: **CSU Experiment Station**



Management of Oakbrush Range

OBJECTIVES

To provide fundamental knowledge concerning the ecology and use of oakbrush types for livestock and big game production.

APPROACH

Oak is being converted to seeded grass and alfalfa mixtures compared to native oakbrush for both elk and livestock grazing. Data will be collected on grazing days, using both converted and control areas. In the case of cattle, animal weights will also be obtained.

Principal Investigators: **C. Wayne Cook, Gary Davis**

Discipline Involved: **Range Science**

Sponsor: **CSU Experiment Station**



Man-Induced and Natural Erosion and Deposition in Semiarid Valleys

OBJECTIVES

Locate within semiarid valleys those areas most susceptible to either erosion or deposition. Relate principles of channel erosion and deposition to gully problems in Colorado.

APPROACH

Repeat surveys will be made in channels in which active erosion and/or deposition was studied about 14 years ago. Sites of natural erosion and aggradation will be studied in detail, and the sedimentary character of channels and recent deposits will be documented. An attempt will be made to relate erosional and depositional processes to the geomorphic characteristics of the drainage systems.

Principal Investigator: **S. A. Schumm**

Discipline Involved: **Geology**

Sponsor: **CSU Experiment Station**



Model Study of River Patterns

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: **S. Schumm**

Discipline Involved: **Geology**

Sponsor: **NSF**



Moisture Stress (San Juan Ecology Subproject)

OBJECTIVES

To determine effects of increased winter snowpack on moisture stress of Engelmann spruce and quaking aspen in the San Juan mountains.

APPROACH

1. Collect weekly measures of tree moisture stress at six forest sites during the growing season.
2. Monitor soil moisture and temperature at same sites.
3. Relate data from 1 and 2 to snowpack, air temperatures, precipitation phenology, and tree biomass.

Principal Investigator: **C. P. Reid**

Discipline Involved: **Forest and Wood Science**

Sponsor: **Bureau of Reclamation**



Nutrition and Food Acceptance as Related to Selected Environmental Factors

OBJECTIVES

To provide basic information for understanding and improving the food acceptance and nutritional situation in the West; specifically (1) to provide essential information on the effects of certain environmental factors on food acceptance and nutrition in specific ethnic, age, and socio-economic groups, (2) to obtain metabolic information pertaining to parameters of nutritional status and to specific interactions of the environmental factors in nutrition, and (3) to evaluate this information toward making recommendations to improve human health.

APPROACH

Investigation will involve human subjects and a regional core sample approach. Attention will be given to specific categories of study to include: immunological response testing, blood, urine, and dietary profiles. The sample and/or categories will be expanded in Colorado with concentration on the elderly with variable socio-economics among the North American population. A family-life social scientist from this station will assist the regional effort.

Principal Investigator: **I. Harrill**

Discipline Involved: **Food Science and Nutrition**

Sponsor: **CSU Experiment Station**



Persistence of Herbicides in Soil

OBJECTIVES

To continue the studies of phenyl pyridazinone herbicides in soil.

APPROACH

A controlled temperature soil study on four pyridazinone herbicides is underway. An analytical method has been developed for two of these herbicides and work is in process for developing analytical methods for the other two.

Principal Investigator: **R. Zimdahl**

Discipline Involved: **Botany and Plant Pathology**

Sponsor: **Great Western Sugar Company**



Phenology

OBJECTIVES

1. Determine average dates of important phenological events for Engelmann spruce and quaking aspen.
2. Correlate phenological events with physically measurable site factors.
3. Note genetic variation in phenology among different plants.

APPROACH

Plots were established for Engelmann spruce on both north and south aspects at each of the four major study sites. In addition, south aspect plots for quaking aspen were established at 2,900 m and 3,200 m on Missionary Ridge.

On each plot, six trees of different age and size classes were studied. Vegetative development was observed every three days on single, randomly selected tagged branches. On the same dates, male and female floral development was recorded, and a dendrometer measurement of radial growth was taken. Also, approximately every two weeks, a wood plug was removed from each study tree through the cambial region of the stem.

Principal Investigator: **G. Fechner**

Discipline Involved: **Forest and Wood Science**

Sponsor: **Bureau of Reclamation**



Photosynthesis of Shortgrass Prairie Vegetation as Influenced by Several Ecological Parameters

OBJECTIVES

To determine the effects of several ecological parameters on the assimilation rate of important grassland vegetation.

APPROACH

Research on that assimilation rate of important grassland species will be conducted using carbon dioxide (CO₂) exchange techniques. Data for assimilation rates as affected by light, temperature, water potential, and stress situations will aid in predicting the amount of energy captured by primary producers per unit of surface area per unit of time. Data obtained from this study should help explain reasons for variations in shortgrass prairie producer biomass through time.

Principal Investigator: **M. J. Trlica**

Discipline Involved: **Range Science**

Sponsor: **CSU Experiment Station**



Phytosociological Class of Subalpine Forests of Southern Rocky Mountains

OBJECTIVES

The major objective of this study is to begin to provide an ecologically-based classification system of the subalpine forests of the Southern Rocky Mountains which will serve as an information retrieval system useful to the land manager.

APPROACH

The phytosociological, environmental, and age structure data will be collected from stands throughout the subalpine region of the Southern Rocky Mountains.

Principal Investigator: **R. L. Dix**

Discipline Involved: **Botany and Plant Pathology**

Sponsor: **USFS**



Phytosociology

OBJECTIVES

To monitor the changes which may occur in the vegetational structure and dynamics of the forested areas of the San Juan Mountains as a result of weather modification program and to provide a phytosociological structure of these forests which may serve as a format on which other studies by other investigators in the project may be expressed.

APPROACH

Quantitative data on the structure and dynamics of aspen, fir, and spruce forest will be collected in the San Juan Mountains. Data on size and age distributions together with vitality estimates of trees, saplings, and seedlings have been taken. Limited environmental data on edaphic factors has also been taken.

Principal Investigator: **R. L. Dix**

Discipline Involved: **Botany and Plant Pathology**

Sponsor: **Bureau of Reclamation**



Regional Oil Shale Study

OBJECTIVES

To determine methods and materials for revegetation and stabilization of waste dumps and excavated areas resulting from oil shale mining and processing.

APPROACH

An interdisciplinary team is organized to conduct the project.

Principal Investigator: **C. W. Cook**

Discipline Involved: **Environmental Resources Center - Interdisciplinary**

Sponsor: **Federal-State-Industry through Colorado Department of Natural Resources**



Review and Critique of Environmental Impact Statements

OBJECTIVES

To critique environmental impact statements submitted to AEC with applications for uranium mine permits.

APPROACH

A team of faculty experts is organized for each review.

Principal Investigator: **Norman Evans**

Discipline Involved: **Environmental Resources Center - Interdisciplinary**

Sponsor: **AEC**



Statistical Variations of a Shortgrass Site

OBJECTIVES

To explore the basic statistical variability of important ecological parameters of a grassland area and to develop computer mapping techniques which would be useful in describing ecological variability over geographical spaces.

APPROACH

The approach was to describe a 1000-acre grassland site at Elgin, Arizona, and to conduct extensive field studies of

the vegetation and soil characteristics. Computer and statistical techniques have been used to analyze the vegetation and soil data in such a way that important statistical variations could be described.

Principal Investigator: **Charles D. Bonham**

Disciplines Involved: **Range Science, Plant Ecology**

Sponsor: **AEC**



Stream and Lake Pollution in the Rocky Mountain National Park

OBJECTIVES

To establish a baseline description of the plant and animal communities of selected lakes and streams subject to contrasting degrees of polluting use in the park and to develop indices of eutrophication for future reference. Three lakes and three streams will be investigated for existing pollution-caused changes.

APPROACH

The planktonic and benthic communities of the three lakes will be sampled intensively during and after the period of heavy visitor use for pollution evidence. Measurements of water chemistry also will be made. The three streams will be evaluated up- and downstream of known pollution entries.

Principal Investigator: **W. J. McConnell**

Discipline Involved: **Cooperative Fisheries**

Sponsor: **National Park Service**



Toxicological Implications of Oil Shale Development in Western Colorado

OBJECTIVES

To ascertain what toxicological insults will be posed on the environment and on animals and plants in the environment as a result of a commercial oil shale operation. The present study area is in Parachute Creek, Colorado along the Colorado River not far from Grand Junction. Of major concern will be trace metals which might get into the environment and be concentrated by plants on land or in the water. The ultimate aim is to predict any possible adverse effects on the environment and on living organisms as a result of commercial oil shale operations.

APPROACH

A wide variety of materials, both biotic and abiotic, are being collected from the vicinity of a pilot plant oil shale operation. These materials, as well as the raw shale and spent shale, are being analyzed for trace metals and other possible environmental poisons using the atomic absorption spectrophotometer and other widely accepted analytical instruments.

Principal Investigator: **C. G. Wilber**

Discipline Involved: **Zoology**

Sponsor: **Thorne Ecological Institute**



Tree Biomass Changes Following Cloud Seeding Operations

OBJECTIVES

To monitor changes in tree biomass over time and to determine if the changes in biomass are related to changes in snow accumulation due to weather modification through cloud seeding.

APPROACH

1) Determine coefficients of linear allometric model for tree bole biomass by destructive sampling, 2) establish total tree biomass on an area basis by application of allometric equations to plot data, and 3) remeasure plots over time and to relate changes in biomass to levels of snowfall that occur over time.

Principal Investigator: **E. Mogren**

Discipline Involved: **Forest and Wood Science**

Sponsor: **Bureau of Reclamation**



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: **A. Berg**

Discipline Involved: **Agronomy**

Sponsor: **Mining Industry**

FISHERY AND WILDLIFE



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**

Sponsor: **USDI**



Effect of Increased Snow on Elk

OBJECTIVES

To determine the effect of increased snow on elk in the San Juan Mountains. Specifically, to determine: a) how the winter distribution of elk is affected by snow, b) how elk calving areas are related to snow, and c) what effect snow-fall has on oak biomass production and the community structure of Gambel's oak in the target area.

APPROACH

Aerial locations of wintering elk as to elevation, aspect, habitat, and snow depth were taken at monthly intervals and were paired with on-site reconnaissance of snow conditions. Seven fixed wing and three helicopter flights were flown during the spring for location of calving elk as to elevation, aspect, habitat, and relation to snow cover and were paired with on-site reconnaissance of calving areas.

Twenty-six plots were located in each of two stands of oak to define the present community structure of the stands and determine their biomass production. An additional 10 plots were located in one stand to determine the timing of major phenological events.

Principal Investigator: **N. H. Steinhoff**

Discipline Involved: **Fishery and Wildlife Biology**

Sponsor: **USDI-Bureau of Reclamation**



Hunter Behavior, Attitudes, and Philosophies

OBJECTIVES

There is ample evidence that recreational hunting is becoming less popular in this country. Professional resource management based on biological principles has also faced increasing opposition and challenge and the possibility that vital game management programs will be reduced.

This research will be directed to the hunter, his behavior, attitudes, and philosophy justifying his activities, with special attention given to experimental and psychological variables.

APPROACH

Data will be gathered through interviews. A random sample of 400 hunters will be drawn from a listing of licensed male hunters. The semi-structured interviews will last one hour. All pertinent data will be recorded. Where applicable, data will be computerized by a CDC-6400 computer. Other data will be tabulated and analyzed.

Principal Investigator: **F. Glover**

Discipline Involved: **Cooperative Wildlife Unit**

Sponsor: **Wildlife Management Institute**



Recent Deer Population Trends

OBJECTIVES

To learn the direction of recent population trends in the contiguous states. To investigate significant factors which determine recent deer population trends.

APPROACH

Key wildlife personnel throughout the country will be contacted. Deer census data will be collected from the states.

Principal Investigator: **D. L. Gilbert**

Discipline Involved: **Fishery and Wildlife Biology**

Sponsor: **Loyalhanna and Landfall Foundation**



**Small Mammals Study in
Cloud Seeding Target Area**

OBJECTIVES

Determination of mortality, population size, age structure of populations, movements of populations, and food habits of cricetid rodents, geomyid ground squirrels and shrews in representative stands within the USDI-Bureau of Reclamation cloud seeding target area, and relate this to snowpack condition and vegetative type.

APPROACH

Studies of home range and litter survival are conducted on a 15.7-hectare grid of 196 nest boxes and 196 live trapping sites. Each live trap site consists of a 5-gallon can pitfall trap and a Sherman live trap located in the center of a square formed by four nest boxes.

Principal Investigator: **H. Steinhoff**

Discipline Involved: **Fishery and Wildlife Biology**

Sponsor: **Bureau of Reclamation**



**Urban Fishery Evaluation
in South Platte River**

OBJECTIVES

The main concern is to evaluate the urban fishery created by stocking channel catfish in the South Platte River, emphasizing the feasibility of continued stocking.

APPROACH

1. Mark all fish to be stocked.
2. Creel census to obtain information concerning angler hours created, catchability, survival, and movement.

Principal Investigator: **W. J. McConnell**

Discipline Involved: **Cooperative Fishery Unit**

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



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 with 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.
4. To determine the role of aquatic invertebrates, species abundance and density as a factor influencing waterfowl, utilization of an area, and productivity.

APPROACH

Waterfowl production was determined by breeding pair counts, nesting surveys, and brood counts. To determine the cost benefit, detailed records were kept on the amount of labor involved in water application, mileage, and cost of water. Routine sampling of aquatic invertebrates from areas utilized by waterfowl provided data for comparison.

Principal Investigator: **F. Glover**

Discipline Involved: **Cooperative Wildlife Unit**

Sponsor: **Bureau of Sport Fisheries**

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**

Sponsor: **CSU Experiment Station**



Evaluation of Natural and Artificial Recharge to the High Plains Groundwater Aquifer (OWRR-A-016-COLO)

OBJECTIVES

To provide mechanisms for the conversion of water on the high plains or similar areas by: 1) developing techniques for evaluating the areal and time distribution of natural recharge; 2) defining procedures for estimating the quantity of water available for artificial recharge on the high plains; and 3) evaluating the use of soil maps for selecting artificial recharge sites.

APPROACH

Selected techniques will be applied and checked against observed recharge and runoff rates of one or more small areas in the high plains. Instrumentation will be installed to observe deep percolation rates and surface runoff on the selected sites. Recommendations will be made on the success of each technique evaluated.

Principal Investigators: **R. A. Longenbaugh, D. B. McWhorter**

Disciplines Involved: **Civil Engineering, Agricultural Engineering**

Sponsor: **OWRR**



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**

Sponsor: **OWRR**



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**

Sponsors: **OWRR, CSU Experiment Station**



Groundwater Reservoir Management

OBJECTIVES

A finite element model is to be developed and tested for use in predicting the changes in water quality due to dispersion in porous media. The finite element technique is also to be developed for groundwater flows.

APPROACH

These developments are applied to flow through a laboratory column of porous media.

The finite difference technique for modeling water quality changes has been applied to the groundwater pollution problem near the Rocky Mountain Arsenal. A final report on this work is due in early 1972. This technique still shows promise for studying groundwater quality changes.

Considerable effort was extended to educate staff members in the State Engineers Office in the use of the digital model for simulating stream-aquifer systems. The South Platte Valley in Phillips County has been modeled and verification for both historic water levels and return flows is underway.

Observation wells were measured and the spring water level report published in cooperation with the U.S. Geological Survey. Work is underway to develop a data bank of all historic groundwater measurements.

Principal Investigators: **D. K. Sunada, R. Longenbaugh**

Discipline Involved: **Civil Engineering**

Sponsor: **CSU Experiment Station**



Groundwater Resources

OBJECTIVES

Develop feasible techniques for efficient development and management of groundwater aquifers. Investigate the applicability of management and development techniques deemed feasible to the various groundwater situations in Colorado and other areas. Train young engineers and scientists in the latest advancements for analysis and management of groundwater resources through the graduate research program. Serve as advisors to the Colorado Ground Water Commission, Colorado Water Conservation Board, State Engineer's Office, and other state and local water agencies on groundwater problems.

APPROACH

Continuing efforts will be directed towards 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**

Sponsor: **OWRR**



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**

Sponsors: **OWRR, CSU Experiment Station**



**Measurement Prediction and Control
of 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 Engineer's 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 ground-water movement.

Principal Investigator: **William Kemper**

Discipline Involved: **Agronomy**

Sponsor: **CSU Experiment Station**



**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 effect 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**

Sponsor: **NSF**

LAND USE PLANNING AND CONTROL



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)**

Sponsors: **USFS, U.S. Army Corps of Engineers, G. F. Kessler and Assoc., Inc.**



Economic and Social Significance of Human Migration for the Western Region

OBJECTIVES

1. To determine the empirically significant factors which influence migration decisions and which can be used to predict the magnitude, routes, and timing of migration.
2. To determine the benefits and costs of migration on an individual family basis.
3. To determine social costs and benefits of migration.
4. To specify policy implications resulting from these analyses.

APPROACH

Phase A of the Colorado work will contribute primarily to the measurement of social costs and benefits of migra-

tion. Empirical tests will be made of the relationship between costs and volume in the production and distribution of social services. Phase B will delineate the capital values of stocks and flows of human resources and the socioeconomic implications for rural and urban areas. Phase C will be a subjective and objective assessment of community costs and benefits of migration as they bear on the inter-institutional adjustment process (social and economic) in selected Colorado towns confronted with dramatic losses or gains in population numbers and associated changes in population structure and composition. The procedure will involve data obtained via personal and mailed interviews, as well as information obtained from secondary sources.

Principal Investigators: **E. C. Knop, R. A. Wykstra, R. C. Walsh**

Disciplines Involved: **Sociology, Anthropology, Economics**

Sponsor: **CSU Experiment Station**



Environmental Management Alternatives for Five Levels of Land Use

OBJECTIVES

1. To devise five resource allocation management plans for each of three resource teams. In order to optimize land use and still insure a minimum of land degradation, it is necessary to formulate a number of land management alternatives and to study the effects of these alternatives on the other portions of the ecosystem.
2. To correlate each of the team's five management strategies for each of 12 study sites of the five major multiple resource allocation management strategies.
3. To establish two extremes of possible resource management for comparison purposes.
4. To develop and use a computerized resource matrix as a management tool.

APPROACH

Eleven students representing six natural resource and one natural science disciplines will form a group. These seven disciplines will be grouped into three main subdivisions: **Range and Forest Resources, Watershed Resources, and Recreational Resources.**

Each group will devise five progressively increasing levels of land management strategies relating to their resource in each of 12 previously selected study sites.

Principal Investigator: **H. R. Alden**

Discipline Involved: **Recreation Resources**

Sponsor: **NSF**



**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**

Sponsor: **CSU Experiment Station**



Modeling of Avalanche Release Processes

OBJECTIVES

To develop avalanche prediction techniques by developing a realistic stress analysis model and by determining the mechanical properties of snow in a form suitable for use in the stress analysis model.

APPROACH

Stress and strain analyses of the snowpack will be made. The strains (and displacements) predicted by the analyses will be compared with the measurements in the actual snowpack. Possible failure criteria may be applied, and the actual behavior of the snowpack with respect to failure can be compared with the computer model. Success will be defined as the prediction of the actual failure within a 24-hour period.

Principal Investigator: **Fred Smith**

Discipline Involved: **Mechanical Engineering**

Sponsor: **Rocky Mountain Forest and Range Experiment Station**



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

OBJECTIVES

1. Continue selection of 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. Determine growth characteristics and environmental tolerances of previously selected plant material planted along actual highway stress areas.
3. Determine feasible and economic methods of propagation and nursery culture to produce selected native and introduced plants in quantity to transplantable size and determine optimum time of transplanting.

APPROACH

Plant previously selected and new species along highway stress areas, establish performance evaluation records for each species, correlate growth response and adaptability to various ecological factors, plant various species in the fall and in the spring and record survival and growth quality and quantity data, continuously record temperature on various slopes and exposures relative to wind and radiant energy, investigate physiological and economic factors relative to propagation and transplanting, and cooperate with the Colorado State Department of Transportation, Division of Highways, in planting operations and site selection.

Principal Investigator: **B. T. Swanson**

Discipline Involved: **Horticulture**

Sponsor: **CSU Experiment Station**



Public Response to a Proposed Alternative to Flood Problems of Boulder Creek

OBJECTIVES

To define social impacts and consequences of available management alternatives for implementation on the Boulder Creek flood plain.

APPROACH

Study both public and leadership response to eight alternatives for management of the Boulder Creek flood plain. Also determine some of the probable causes to the responses.

Principal Investigator: **D. W. Hill**

Discipline Involved: **Political Science**

Sponsor: **U.S. Army Corps of Engineers**



Rates and Consequences of Population Change

OBJECTIVES

To correlate the rates of population changes in the Rocky Mountain region with selected consequences: population structure, housing supply, retail activity, agriculture, and public expenditures.

APPROACH

The Rocky Mountain region will be studied as a total region, or component states, and as a set of approximately 500 counties. Within these areas markedly different population change rates occurred between 1950 and 1970.

Principal Investigators: **B. Dotson, T. Van Valey**

Discipline Involved: **Sociology and Anthropology**

Sponsor: **NIH**



Regional Analysis of Grassland Environmental Systems

OBJECTIVES

1. Design systems for necessary data acquisition; gather appropriate existing data on the resource base and its function.
2. Develop and utilize simulation models that can be utilized by resource managers to investigate ecological impacts of management strategies.

3. Employ existing and develop and test new methodologies by which resource managers can develop optimal resource management plans and identify social, economic, and political requirements that influence their management of the ecological resource base.
4. Assess and quantify rural-urban interactions which have major impact on land planning.

APPROACH

Three major groups are involved in the operation of natural resource systems: a technical group (data system, simulation models and experiments); a management group; and a user group. Facsimile groups will be established for each of these groups, members of which will be drawn from the real-world counterpart whenever possible.

The Great Plains area of the United States will be the general research area with the Pawnee National Grasslands being the specific subject of study.

Principal Investigator: **D. Jameson**

Discipline Involved: **Range Science**

Sponsor: **NSF**



Simulation of Regional Data Center for Decision Making in Forest Management

OBJECTIVES

To establish a group to simulate a regional data processing center geared to supply fast response to management inquiries related to silvicultural practices on the Black Hills National Forest.

APPROACH

1. Modify computer program (TEVAP) to allow various alternatives relating to even-aged regeneration.
2. Profile a detailed report including: a) potential usefulness of TEVAP and related programs to the national forest system; b) evaluate the feasibility of establishing a regional data processing center to service individual national forests; c) determine expected demands on a center in terms of processing requests; and d) determine expected quantity and quality of manpower necessary to operate a center.
3. Simulate activities of a Regional Data Center throughout the life of the contract.
4. Prepare operational versions of the programs and data banks plus instructions for using them for use by the Black Hills National Forest.

Principal Investigator: **W. E. Frayer**

Discipline Involved: **Forest and Wood Science**

Sponsor: **Rocky Mountain Forest and Range Experiment Station**



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: **Agromony**

Sponsor: **CSU Experiment Station**

OPEN SPACES AND RECREATION



Ecology Themes in the Great Plains Natural Region

OBJECTIVES

To conduct an ecological theme analysis of the Great Plains Natural Region including: a) a general discussion of the ecological natural history themes in the region, b) a separate analysis of each significant theme, c) a description of each major type of representation of each theme, d) an inventory of sites representative of themes, e) an evaluation of sites representative of themes, and f) liaison with geological theme analysis consultants.

APPROACH

Procedures used during calendar year 1971 included secondary review of published literature, interviews, and field inspection of established and potential park, monument, and landmark sites.

Principal Investigators: **A. T. Cringan, R. L. Dix**

Discipline Involved: **Fishery and Wildlife Biology**

Sponsor: **National Park Service**



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. Subobjectives 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: **R. G. Walsh**

Discipline Involved: **Economics**

Sponsor: **CSU Experiment Station**



Northern Colorado Outdoor Nature Center

OBJECTIVES

Develop a Model K-12 Environmental Education Program for schools to include a K-12 curriculum guide, an outdoor nature center, and an in-service training program for teachers and naturalists.

APPROACH

1. Comprehensive objectives for the program have been specified.
2. Teachers and consultants have prepared a curriculum guide for themes, activities, and resources for schools.
3. Nature Center trails have been developed.
4. A continuous in-service program is available for teachers.
5. Continuous evaluation is being carried out with the assistance of the Human Factors Laboratory at Colorado State University.

Principal Investigator: **H. Bruner**

Discipline Involved: **Education**

Sponsor: **Poudre R-1 School District**

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, J. C. Ward**

Disciplines Involved: **Microbiology, Civil Engineering**

Sponsor: **CSU Experiment Station**



Arctic Lagoon Microbiology

OBJECTIVES

This program was initiated during the summer of 1971 at Point Barrow, Alaska, to study the ecological interactions that take place in a coastal, salt-water lagoon and how they relate to sewage disposal by "lagooning" in high latitude regions.

APPROACH

Field studies consisted of semi-weekly sampling of water and bottom sediments to determine microbial interactions

and changes in populations. Runoff water was also studied extensively during June. Post-field work is being done on certain public health aspects, and selected populations are being screened to determine their physiological potentiality for possible use as indices of fecal pollution.

Principal Investigator: **William Boyd**

Discipline Involved: **Microbiology**

Sponsor: **Office of Naval Research**



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**

Sponsor: **OWRR**



Land Application of Metropolitan Denver Sewage Sludge

OBJECTIVES

1. To study recycling of sludge materials into the soil.
2. To determine maximum application rate without causing mineral, organic, and pathogenic pollution of soil or water.

APPROACH

A field study will be set up on the sandy soils of western Adams County. Three cropping situations will be used: fallow, grain sorghum, and millet. Five rates of

sludge ranging from 0 to 8 acre-inches will be applied to each cropping situation in a single application prior to planting and final seed bed preparation.

Soil depth samples at 5 to 10 different depths will be taken at the beginning of the experiment, at mid-season, and after harvest.

Plant yields will be measured from each plot. Yield data will be correlated with sludge application rates. Plots will be sprinkler irrigated.

Principal Investigators: **B. Sabey, W. E. Hart**

Disciplines Involved: **Agricultural Engineering, Agronomy**

Sponsor: **Metropolitan Denver Sewage Disposal District No. 1**



Lime Disinfection of Sewage Bacteria at Low Temperatures

OBJECTIVES

To make a laboratory study of the potential use of lime as a disinfectant agent for the bacteria in sewage at low temperatures. In sparsely populated areas in the far north, if lime is available, the successful flocculation of solids and destruction of potential bacterial pathogens could be a valuable sewage treatment process to abate pollution.

APPROACH

Basic studies in the laboratory will be made at 5 C with comparison tests at 1 C and 10 C of raw sewage from a municipal plant. Specific data will be gathered on the inter-related mechanisms of flocculation and disinfection as influenced by temperature, contact time, and pH.

Principal Investigator: **S. M. Morrison**

Discipline Involved: **Microbiology**

Sponsor: **EPA**



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 and -20 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**

Sponsor: **OWRR**



**Metropolitan Water Intelligence
Systems Phase I**

OBJECTIVES

The basic objectives are to:

1. Investigate and describe modern automation and control systems for the operation of urban water facilities with emphasis on combined sewer systems.
2. Develop criteria for managers, planners, and designers to use in the consideration and development of centralized automation and control systems for the operation of combined sewer systems.
3. Establish the feasibility constraints, and both technical and social, of automation and control systems for urban water facilities with emphasis on combined sewer systems for a wide range of size and type of urban areas.

APPROACH

The project has been divided into eight tasks, each contributing to the total objective. Each task will be

summarized in a technical report and the total effort will be summarized in a final completion report.

Principal Investigators: **M. L. Albertson, G. Smith**

Discipline Involved: **Civil Engineering**

Sponsor: **Office of Water Resources**



Sludge Disposal in Soil-Coors Company

OBJECTIVES

To analyze a sludge disposal plan and recommend alternatives if possible.

APPROACH

Appropriate scientists are engaged to examine data and interpret it within the context of a disposal plan.

Principal Investigator: **N. A. Evans**

Discipline Involved: **Environmental Resources Center -
Interdisciplinary**

Sponsor: **Wright-McLaughlin Engineers**



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 the air passing through the wind tunnel.
3. Outdoor measurements of evaporation from a spray nozzle system over a shallow pond of about 10,000-square-foot area.

Principal Investigator: **George O. G. Lof**

Discipline Involved: **Civil Engineering**

Sponsor: **Office of Saline Water**



**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

Sponsors: OWRR, CSU Experiment Station

WATER CYCLE



**Development of Computer Program
Application—Stochastic Hydrology**

OBJECTIVES

To develop a feasible computer program for the analysis of hydrologic time series and for the generation of large samples of inferred periodic-stochastic models of these series.

APPROACH

The present research results on other projects are reviewed from the point of applicability in the USDI-Bureau of Reclamation practice. By a cooperation with USDI-Bureau of Reclamation employees, the practical methods of analysis and simulation of time series are searched for.

Principal Investigator: V. Yevjevich

Discipline Involved: Civil Engineering

Sponsor: Bureau of Reclamation



**Energy Transfer from Bodies of Water
due to Evaporation and Conduction**

OBJECTIVES

Investigate various methods of determining the surface transfer of energy across an air-water interface.

APPROACH

Field measurements of wind speed temperature, and humidity are used to evaluate various methods of computing evaporation and energy transfer.

Principal Investigator: H. E. Jobson

Discipline Involved: Civil Engineering

Sponsor: NSF



**Evaporation of Water as Related to Wind
Barriers (OWRR B-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 to:

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 are 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**

Sponsors: **OWRR, CSU Experiment Station**



Hydrologic Stochastic Processes

OBJECTIVES

To investigate structurally and to describe mathematically the hydrologic stochastic processes of the nature of the water demand time series.

APPROACH

The most modern theory of stochastic processes, as well as some techniques developed under this project, are used to analyze the character of hydrologic and water resource time series, and to describe them mathematically in the most condensed forms.

Principal Investigator: **V. Yevjevich**

Discipline Involved: **Civil Engineering**

Sponsor: **NSF**



Hydrometeorological Research

OBJECTIVES

To evaluate the water resources of West Africa as a function of the hydroclimatological regime and the large-scale atmospheric circulation. To determine the demand, present and projected supply, control, and quality management of the water resources. To develop the concept of water resource system, the most efficient approach to water development, aimed to meet the needs and to benefit the economy, society, and the environment. Also, to provide training of students in these fields (Cameron and Ghana).

APPROACH

1. Data collection.
2. Data analysis.
3. Optimum design of water resources systems.

Principal Investigator: **E. Reiter**

Discipline Involved: **Atmospheric Science**

Sponsor: **NSF**



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 determine 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**

Sponsor: **CSU Experiment Station**



**Laboratory Cloud Simulation
to Support Weather**

OBJECTIVES

1. Test cloud seeding devices.
2. Assist researchers desiring use of Simulation Laboratory facilities.
3. Describe the effect of composition on the nucleation characteristics of silver iodide.
4. Refine and extend usefulness of cloud chambers and related equipment for research and testing purposes.

APPROACH

1. Run tests comparing effectiveness of NH_4I and NAI complexed AgI acetone solutions.
2. Design and build accurately controlled cloud source and automatic counting systems for isothermal chamber.

Principal Investigator: **L. Grant**

Discipline Involved: **Atmospheric Science**

Sponsor: **NSF**



Large Continental Droughts

OBJECTIVES

To study the physical and probabilistic prediction of droughts as well as engineering, economic, and social impacts of large continental droughts.

APPROACH

Physical predictability of droughts has been investigated by relations of variables preceding each other in time. Probabilities of large droughts are studied by the

application of stochastic processes. Simulation techniques are used to study probabilities of regional droughts. Uncertainties in droughts are specially analyzed by the advanced methods. It is found that it is nearly impossible to predict droughts from immediate physical phenomenon known; the ocean temperature conditions used as predictors do not show a larger possibility than one month in advance prediction. A technique has been developed for simulating large numbers of station series of precipitation in a region. It is shown that historic droughts are often non-representative of the samples in which they have been observed, and a technique is being developed for determining representative droughts. Uncertainties in drought information on economic decisions are evaluated. Several theses are in progress on this subject.

Principal Investigator: **V. Yevjevich**

Discipline Involved: **Civil Engineering**

Sponsor: **NSF**



**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**

Sponsor: **OWRR**



Numerical Simulation of Orographically Induced Precipitating Clouds

OBJECTIVES

The primary objective of this project is to develop a numerical model to simulate the life cycle of a cold, orographically induced, precipitating cloud.

APPROACH

The project is being carried out in two phases. In phase I a model is formulated which does not allow the condensation products to fall out of the air. In phase II the condensation products will have a finite fall velocity, and it is our intention to make use of the most recent information from the field program that is being carried out in the Colorado Rockies to realistically model this phenomenon.

Principal Investigator: **E. C. Nickerson**

Discipline Involved: **Civil Engineering**

Sponsor: **NSF**



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**

Sponsor: **CSU Experiment Station**



Probability and Statistics in Hydrology

OBJECTIVES

To deliver a practical course on probability and statistics as applied to hydrology and water resources for the employees of the USDI-Bureau of Reclamation.

APPROACH

The present program of the CSU course CE622 has been adjusted for the purpose of meeting the background and the interest of about 20 USDI-Bureau of Reclamation employees.

Principal Investigator: **V. Yevjevich**

Discipline Involved: **Civil Engineering**

Sponsor: **USDI-Bureau of Reclamation**



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 directed : 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**

Sponsor: **NSF**



The Role of Small-Scale Convection on Transport Water Vapor

OBJECTIVES

To investigate the vertical transport of water vapor in the subcloud layer.

APPROACH

All possible physical processes which could account for the transport of observed amounts of water vapor will be examined. A model of these processes will be constructed to see if the interaction of these processes can explain observed variations.

Principal Investigator: **S. Cox**

Discipline Involved: **Atmospheric Science**

Sponsor: **ESSA**



Significance of Cumulonimbus Momentum Transport for Atmospheric Processes

OBJECTIVES

To identify the vertical momentum transports by cumulus clouds. This should improve one- and two-day forecasting in the tropics where cumulus momentum takes place.

APPROACH

Large samples of upper air and rainfall information will be taken on a daily and monthly basis. Heavy rainfall and thunderstorm activity also will be studied in association with environmental cumulus potential buoyancy, vertical shears, and height deviation on the pressure surfaces.

Principal Investigator: **W. Gray**

Discipline Involved: **Atmospheric Science**

Sponsor: **NSF**



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, nonuniform 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**

Sponsors: **OWRR, CSU Experiment Station**



Theory and Experiments in the Prediction of Small Watershed Response (Phase II)

OBJECTIVES

To evaluate the accuracy of mathematical models in predicting the hydrographs of flood runoff by comparison with both the measured hydrographs from experiments on the outdoor rainfall-runoff facility and the recorded hydrographs from natural watersheds.

APPROACH

Mathematical models of watershed response to flood producing rainfall are to be verified in the 1-acre CSU outdoor experimental rainfall-runoff 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. Yevjevich**

Discipline Involved: **Civil Engineering**

Sponsor: **OWRR**

WATER QUALITY MANAGEMENT AND PROTECTION



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**

Sponsor: **FWOA**



Developing Improved Solvent Extract Atomic Method for Determining Trace Elements

OBJECTIVES

1. To develop more sensitive methods for determining trace elements in water by atomic absorption.
2. To develop improved solvent extraction methods for concentrating trace elements from water.

APPROACH

Several complex experimental procedures are being used.

Principal Investigator: **R. K. Skogerboe**

Discipline Involved: **Chemistry**

Sponsor: **Federal Water Pollution Control**



Eastman Kodak Water Quality Study

OBJECTIVES

To gather data on the environmental quality of the Poudre River above and below the Kodak development for the periods before and after initiation of manufacturing operations.

APPROACH

The data in this project are being gathered by cooperative arrangements between the director (SMM) and Drs. G. Post, E. Reed, and K. Schiager. The observations include the following parameters of river quality; chemical content, bacteria, some physical measurements, fish survey, limnological data, and radioactivity.

Principal Investigator: **S. M. Morrison**

Discipline Involved: **Microbiology**

Sponsor: **Eastman Kodak Company**



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: **R. A. Young**

Discipline Involved: **Economics**

Sponsors: **OWRR, CSU Experiment Station**



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**

Sponsor: **Bureau of Reclamation**



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**

Sponsors: **CSU Experiment Station, FWQA**



Institutional Requirements for Optimal Water Quality Management in Arid Urban Areas

OBJECTIVES

1. To develop more effective programs for achieving water quality goals in areas which are rapidly changing from rural to urban in character, and which are faced with critical water shortage problems as well as serious water quality problems.
2. To determine the extent to which present institutions would prevent implementation of these programs.
3. To identify needed changes in water quality and water quantity management institutions, policies, and practices.
4. To develop a model program for management of water quality in water-short urban areas.

APPROACH

From water information available, a simulation of the water supply and waste water disposal system would be developed. The model would be designed to simulate the existing mode, as well as alternative modes of the system, and would incorporate capability for projected changes in water demand, as well as analysis of the costs of water supply, water treatment, waste water treatment, and waste water disposal for each of the system modes. Systems analysis would be applied to the model in order to determine the least costly combination of actions required to attain any target stream quality criteria. The system will incorporate all of the physical, chemical, and biological parameters normally used to define stream quality, establish water quality requirements of various water uses, or to characterize various wastes.

Principal Investigators: **G. V. Skogerboe, R. C. Ward, W. Walker**

Discipline Involved: **Agricultural Engineering**

Sponsor: **OWRR**



Irrigation Return Flow Quality Literature Abstracting

OBJECTIVES

1. To pull together published results from related research efforts and make these available to others in the field.
2. To maintain a current summary of literature within the irrigation return flow category within the files of the Water Resources Scientific Information Center EDP facility.

3. To identify gaps in the collective effort and stimulate research to fill these gaps.
4. To promote (and assist in) application of research results to the solution of water pollution problems.

APPROACH

To meet these objectives, a selected list of 100 publications will be reviewed, and articles pertaining to irrigation return flow quality will be abstracted. Abstracts and copies of the articles abstracted will be provided to the Water Resources Scientific Information Center (WRSIC) and to the FPA laboratory at Ada, Oklahoma. A survey of these publications indicates that approximately 1000 articles will be abstracted annually from the selected list of publications.

Principal Investigator: **G. V. Skogerboe**

Discipline Involved: **Engineering Research**

Sponsor: **EPA**



**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 Investigator: **Daniel K. Sunada**

Discipline Involved: **Agricultural Engineering**

Sponsor: **CSU Experiment Station**



**Pesticide Mobility and Degradation
in Soil-Water Systems**

OBJECTIVES

To identify the principal degradation productions 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**

Sponsor: **CSU Experiment Station**



Pollution Study on the Yellowstone River

OBJECTIVES

To determine the degree to which quantity and quality of aquatic life in the Yellowstone River is changed by existing sewage inflows and to use this information to estimate levels of eutrophication which will begin to cause noticeable and undesirable changes in the river biota.

APPROACH

A comparison will be made of bottom-dwelling biota in relation to zones of increasing pollution exposure. Data will be examined for quantitative response by biota to differences in ambient sewage concentrations which might serve as a basis for predicting the results of increased or decreased sewage loading.

Principal Investigator: **W. J. McConnell**

Discipline Involved: **Cooperative Fisheries Unit**

Sponsor: **National Park Service**



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**

Sponsor: **USGS**



Refractory Organic Matter: An Index of Eutrophic Level

OBJECTIVES

The objectives of the research were: 1) to measure instantaneous amounts of organic carbon, both particulate and dissolved, in a number of freshwaters ranging from unproductive alpine tarns to moderately productive reservoirs on the plains; 2) to determine if a fraction of particulate organic carbon refractory to bacterial decomposition could be demonstrated; and 3) to relate refractory or nonrefractory organic carbon to trophic levels of the waters studied.

APPROACH

Carbon is connected to carbon dioxide by acid-persulfate digestion and infrared adsorption measured in a Bechman infrared analyzer.

Principal Investigator: **Edward B. Reed**

Discipline Involved: **Zoology**

Sponsor: **EPA**



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**

Sponsor: **CSU Experiment Station**



Transport of Salts in Irrigation Return Flow (OWRR-A-017-COLO)

OBJECTIVES

To establish a method of predicting the transport, in partially saturated soils, of chemical species that interact significantly with the soil.

APPROACH

The sulfate ion will be studied as it interacts with the soil in laboratory soil columns. The conditions influencing the movement of water will be varied so that chemical transport in both steady and cyclic flow of water can be observed. Data from the research and the knowledge presently available concerning sulfate reactions in soils will be used to develop a model of the source-sink component. All soils, solutions, and conditions will be selected so that the reactions of sulfate can best be identified, characterized, and treated quantitatively.

Principal Investigators: **D. B. McWhorter, D. K. Sunada, A. Klute, V. C. Cole**

Disciplines Involved: **Agricultural Engineering, Civil Engineering, Agronomy**

Sponsors: **OWRR, USDA-ARS**



**Waste Water Disposal for
Isolated Mountain Sites (OWRR-A-20-COLO)**

OBJECTIVES

1. To investigate the process of evaporation of waste waters from isolated mountain cabins at various elevations in Colorado.
2. To determine the costs involved.
3. To produce a detailed design of an evaporation facility incorporating features for precipitation interception.

APPROACH

1. From existing data, predict as closely as possible the expected evaporation rates as a function of elevation for Colorado latitudes.
2. Using commercially available materials, estimate the unit costs of an evaporation facility.
3. Obtain experimental data on evaporation rates as a function of elevation and time of year for Colorado latitudes, and use this information to complete a detailed design of the evaporation facility.
4. Test the design at various elevations and observe possible disadvantages such as odor, etc. Modify the design as necessary.

Principal Investigator: **J. C. Ward**

Discipline Involved: **Civil Engineering**

Sponsor: **OWRR**



**Water Law in Relation to Environmental
Quality (Title II Program)**

OBJECTIVE

To define the activities of man, and the cultural and institutional influences which have adversely affected the natural freshwater aquatic environment in the United States, thus to determine the importance of water law as one of the influences. To determine the effects of traditional, statutory, and case law relating to water and wetlands on environmental quality with particular reference to recreational land aesthetic values and fishery and wildlife resources. To analyze the legal devices used by state and federal governments to prevent the destruction or physical degradation of water and wetlands environments. To determine by onsite inspections the effectiveness of legal measures which have been developed. To determine the environmental benefits by case study method within western states currently operating under stream preservation laws. To develop a model law that would promote

the preservation and enhancement of our aquatic environment, and to develop guidelines for an administrative institution for its implementation.

APPROACH

The study involves an analysis of water law as it affects environmental quality with specific emphasis upon recreational and aesthetic values and fishery and wildlife resources. Intensive attention will be given to the relationship of water law to minimum stream flow, to minimum or permanent water levels in lakes and reservoirs, and the legal restrictions upon disturbance of natural streams, lakes, and wetlands by highway construction, residential or industrial developments. The effects of legal or administrative efforts to protect the aquatic environment will be checked in the field by visits to sites in the western states. A model law will be developed.

Principal Investigators: **G. Swanson, G. Radosevich**

Discipline Involved: **Fishery and Wildlife Biology**

Sponsor: **OWRR**



**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.

APPROACH

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**

Sponsor: **OWRR**

WATER QUANTITY MANAGEMENT AND CONTROL



**Analysis of Colorado Precipitation
(OWRR-A-018-COLO)**

OBJECTIVES

To conduct a systematic study of the distribution of precipitation across Colorado. The analysis will include study in both time and space dimensions to determine precipitation trends, variations that exist in precipitation records, and how the annual regime of precipitation is determined.

APPROACH

The study will be based upon an analysis of existing precipitation records in Colorado. It will involve three areas of Colorado: western Colorado oil shale region, western slope, and eastern slope and plains.

Principal Investigator: **J. L. Rasmussen**

Discipline Involved: **Atmospheric Science**

Sponsor: **OWRR**



**Consolidation of Irrigation Systems:
Phase II--Engineering, Economic, Legal, and
Sociological Requirements (OWRR B-083-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 will involve the social and economic aspects of attaining consolidation along with legal and engineering requirements.

APPROACH

The first phase was 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: **G. V. Skogerboe, G. E. Radosevich, E. Vlachos, P. C. Huszar**

Disciplines Involved: **Agricultural Engineering, Economics, Sociology and Anthropology**

Sponsors: **OWRR, CSU Experiment Station**



Determination of Snow Depth and Water Equivalent by Remote Sensing (OWRR-A-019-COLO)

OBJECTIVES

1. To determine how precisely snow depth and water equivalent can be estimated from snowmelt patterns as detected by air photography in a mountain watershed.
2. To develop an operating system for the routine determination of snow depths and incremental accumulations photogrammetrically.
3. To determine the accuracy and precision of the system for different field conditions.
4. To evaluate the economics of these procedures compared with current practice in terms of time, cost, and accuracy.

APPROACH

There will be three complementary phases:

1. Air photographs will be made of the study area seven times between March 1 and July 1. Sets of five to nine snow stakes are installed at 30 sites representative of the five major ecosystems, two major aspects, and three elevational strata between 2100 m and 3500 m. Patterns of snowmelt within each stratum of ecosystem, aspect, and elevation will be measured from the air photos and related to ground measurements of snow depth and water equivalent. A multiple regression model, employing important variables, will be used to improve the precision of the prediction of snow depth and water equivalent.
2. The second phase will be based on the use of currently existing aerial photography of the Wolf Creek Pass area. A comparison of the photo-observed versus the ground-observed will provide a test of the photogrammetric system.

3. A ground control will be located and targeted to be visible during the snow season. Subsequent photography will be analyzed.

Principal Investigators: **Harold Steinhoff, J. Ruff, L. Teller, A. Barnes, M. Skinner**

Disciplines Involved: **Fishery and Wildlife Biology, Watershed Science, Civil Engineering**

Sponsor: **OWRR**



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**

Sponsor: **CSU Experiment Station**



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

OBJECTIVE

This is a study of economic, political, and legal ramifications of Colorado water laws.

APPROACH

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:

1. Effects of changes in water law on major water use groups.
2. Effects of changes in water law on the Colorado economy.

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: **K. Nobe, D. Hill, G. Radosevich, E. Flack**

Disciplines Involved: **Economics, Political Science, Civil Engineering**

Sponsor: **OWRR**



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 Investigator: **W. F. Hart**

Discipline Involved: **Agricultural Engineering**

Sponsor: **CSU Experiment Station**



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**

Sponsor: **OWRR**



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**

Sponsor: **CSU Experiment Station**



Irrigation Practices, Return Flow Salinity, and Crop Yields

OBJECTIVES

To evaluate the effects of various irrigation practices on the salinity of irrigation return flows as well as crop production, and to demonstrate that improved farm irrigation water management can reduce mineral water quality degradation simultaneously with increasing crop yields and farm profits.

APPROACH

An area of land will be divided into approximately 100 plots, each 100 feet square. Each plot will be provided with both an individual drainage system and a solid-set sprinkler irrigation system. The sprinkler system will be designed to permit a variety of controlled irrigation treatments on the crops.

Four crops will be planted and several irrigation treatments will be used on each crop.

Principal Investigator: **G. V. Skogerboe**

Discipline Involved: **Agricultural Engineering**

Sponsor: **CSU Experiment Station**



Machine Storage of Water Records

OBJECTIVES

To initiate a pilot program to determine the most feasible and economical way of processing Colorado water diversion data.

APPROACH

Methods of machine data processing will be evaluated as to cost and reliability for storing, and making available for study all historical and future water diversion data for Colorado.

Principal Investigator: **R. Longenbaugh**

Discipline Involved: **Civil Engineering**

Sponsor: **State of Colorado Division of Water Resources**



**Measurements of Snowfall Rates Using
Long Path Radiation Attenuation**

OBJECTIVES

To design, test, and calibrate a long path sensor system for remote determination of snowfall rates and amounts.

APPROACH

Testing of the basic theory, that detection of snowflakes in the view-volume of an infrared radiometer looking at a constant temperature target was possible, took place during January through April, 1971. Design of a lens system to present the radiometer with a cylindrical view-volume is in progress by researchers. Tests involving an infrared radiometer viewing a blackbody target in an insulated, constant temperature box determined that such a system as that proposed is feasible for remote determination of snowfall rates and amounts. A preliminary report has been presented to the USDA Forest Service.

Principal Investigator: **W. M. Marlatt**

Discipline Involved: **Watershed Sciences**

Sponsor: **USFS**



Mechanics of Flow and Sediment Transport

OBJECTIVES

To obtain and analyze field measurements of hydraulic and sediment variables in a sand-bed channel. To study sediment transport, resistance to flow, bed configuration, and scour and fill in a sand-bed channel under equilibrium and nonequilibrium flow conditions.

APPROACH

Data were collected to describe the hydraulic and sediment transport variables for a range of flows and bed configurations. Data obtained included sounder profiles of the channel bed, vertical velocity profiles, sediment concentration profiles, samples of bed material, and water-surface slope.

Principal Investigator: **James P. Bennett**

Discipline Involved: **Civil Engineering**

Sponsor: **USGS**



**Rapid Measurement of Snow Depth by
an Airborne Monocycle Radar**

OBJECTIVES

To develop an airborne monocycle radar to measure the depth and water content of snow packs from stationary and moving ground-based platforms.

APPROACH

Investigate the optimum frequency for acceptable system performance. Suitable pulse generators and antennas for a mobile system will be designed and built.

Principal Investigator: **Roger Vickers**

Discipline Involved: **Electrical Engineering**

Sponsor: **USDI-Bureau of Reclamation**



**Snow-Air Interaction and Management
of Mountain Watershed Snowpack**

OBJECTIVES

1. Design and carry out an experiment to evaluate the interface transport of water vapor between the snow surface and the atmosphere.

2. Carry out an experiment to test the effectiveness of procedures for increasing the water supplies derived from the alpine zones of mountain watersheds.

APPROACH

Research will be conducted at two existing facilities engaged in atmosphere research and snow hydrology: the College of Forestry mountain site at Pingree Park, Colorado and the Department of Atmospheric Science observatory at Climax, Colorado.

The research will include a study of interface processes in which snowpack and overlying atmosphere will be considered, and the energy budget will be evaluated.

A study will also be made of snow management procedures over alpine areas as a technique for increasing water supply.

Principal Investigator: **J. Rasmussen**

Discipline Involved: **Atmospheric Science**

Sponsor: **OWRR**



Systematic Design of Legal Regulations for Optimal Surface-Groundwater Usage (OWRR-B-076-COLO)

OBJECTIVES

To design rules for the conjunctive use of surface and groundwater which satisfy the law and maximize the beneficial use of the waters.

APPROACH

The simultaneous behavior of surface flow and groundwater in a river aquifer system will be analyzed to develop a mathematical model of the physical system. Legal constraints on water distribution and measures of beneficial use will be incorporated into the model. The model will then be used to test possible operational rules for the conjunctive system.

Principal Investigators: **H. J. Morel-Seytoux, R. A. Young, G. E. Radosevich, H. P. Caulfield**

Disciplines Involved: **Civil Engineering, Economics, Political Science**

Sponsor: **OWRR**



Systems of Management for Optimum Water Utilization

OBJECTIVES

1. Manage and operate an irrigated farm as an economic unit, keeping a complete set of records for economic analysis.
2. Conduct research to determine the effects of crops, soils, topography, and water supply on water and fertilizer management, adaptability of irrigation systems, adaptability of cultural systems, irrigation practices, environmental quality, and economic return on farms in southwest Colorado.
3. Develop management systems for optimum production, water use, and soil and water conservation under non-irrigated conditions of Colorado.

APPROACH

An irrigated farm of approximately 300 acres will be established to evaluate both gravity and sprinkler irrigation. Water application, groundwater condition and quality, and quantity of return flow will be measured. Field studies will be used to evaluate soil, water, and crop management practices with economic evaluation of various systems.

Principal Investigators: **K. Brengle, H. Mann, H. Moore, R. Tinnermeier, W. Hart, D. F. Hervey**

Disciplines Involved: **Agronomy, Agricultural Engineering, Economics, CSU Experiment Station**

Sponsor: **CSU Experiment Station**



Use of Remote Sensing Data for Describing Large River Environment

OBJECTIVES

There are two objectives in this proposed research. Objective 1 deals with the preliminary feasibility evaluation of multispectral remote sensor data for identifying certain features in and along the river, and the evaluation of color and color infrared photography, multiband photography, and thermal infrared imagery on their own individual merit. Objective 2 is to obtain a preliminary evaluation of the use of analytical photogrammetry for precisely describing geometric shapes pertaining to the characteristic shapes found in a river channel.

APPROACH

Through close coordination with the River Stabilization Branch, certain of those existing test-site reaches along the Mississippi in the Vicksburg District will be selected which

portray the items of interest listed under objectives 1 and 2 above. Adequate ground truth will be established for those conditions pertaining to objective 1, and additional ground control will be added where necessary for those items listed under objective 2. Flights will be accomplished with appropriate sensors (aircraft, flight crew, and airborne sensors will be provided by Colorado State University). Airborne sensors will include an RC-8 precision mapping camera (or equivalent), a multiband camera system, and a thermal infrared imaging system). Recordings at the aircraft flight level and at ground level of pertinent data such as temperature, solar radiation, humidity, atmospheric pressure, and wind velocity and direction will be made.

Principal Investigator: **D. B. Simons**

Discipline Involved: **Civil Engineering**

Sponsor: **U.S. Army Corps of Engineers**



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.

Principal Investigator: **M. L. Albertson**

Disciplines Involved: **Civil Engineering, Agronomy, Sociology and Anthropology, Political Science, Economics, and Agricultural Engineering**

Sponsor: **Agency for International Development (AID)**



Water Resources Hydraulics

OBJECTIVES

1. To improve 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.

2. 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 will be studied. 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 initially involve 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**

Sponsor: **CSU Experiment Station**



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**

Sponsor: **CSU Experiment Station**



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**

Sponsor: **State of Colorado Division of Water Resources**

WATER RESOURCES PLANNING



Classification and Designation of Water for Specific Use

OBJECTIVES

To determine the feasibility of classifying water bodies and segments thereof by potential uses, and the desirability of designating certain water for specific uses.

APPROACH

Three major questions are studied to meet this objective: 1) should water be classified?, 2) can water be classified?, and 3) how can water be classified? The first question is dealt with in terms of the values and limitations of classification. In order to answer questions 2 and 3, an effort is made to study as many of the different classification systems as possible.

Principal Investigators: **A. Wilcox, R. Aukerman**

Discipline Involved: **Recreation Resources**

Sponsor: **National Water Commission**



Construction of a Computer-Based Landscape Model of the Cache la Poudre Watershed

OBJECTIVES

1. Collect the data and construct a high resolution computer model of the basic landscape features of the Little South Fork watershed of the Cache la Poudre River including the characteristics of elevations, slope, aspect, geologic substructure, vegetation types, stand density, and stream net.
2. Utilize this model of the landscape as the input to a watershed simulation model and compare to conventional methods of outlining hydrologic units for such models.

APPROACH

Aircraft-level remote sensing techniques will be employed to obtain up-to-date maps of characteristics of the basin not already available in map form which are needed as overlays in the landscape model. A ground test will be prepared with range comparable in scale, computer accessibility, and detail to the resolution of the ERTS (Earth Resource Technology Satellite--Model A) data to be available for this basin in a digital form in 1972.

Principal Investigator: **L. D. Miller**

Disciplines Involved: **Watershed Science, Remote Sensing, Air Photo Interpretation, Computer Science**

Sponsor: **CSU Experiment Station**



Correlation of Economic and Physical Factors--Irrigation

OBJECTIVES

To obtain crop production response from irrigation in relation to nitrogen fertilizer levels, and to evaluate for correlation purposes the soil and climate variables influencing yield response. To evaluate the responses in a statistically derived production function, and to relate cultural, soil, climatic, and yield factors in an economic analysis useful for selection of lands for irrigation development.

APPROACH

Field plots were established to evaluate yield response to nitrogen fertilizer treatments and irrigation levels based upon the design recommended by the Center for Agricultural and Economic Development, Iowa State University. 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 Investigator: **R. Danielson**

Discipline Involved: **Agronomy**

Sponsor: **Iowa State University**



Development of Techniques for Estimating the Potential of Water Resources Development in the Western Region of the United States for Achieving National and Regional Social Goals

OBJECTIVES

To develop methods and techniques in which the social effects of water resource management decisions, particularly investment streams, may be more specifically identified and measured in the arid and subhumid regions of the western United States. Of particular concern are the possible contributions of alternative water resources development policies to selected national and regional goals.

APPROACH

A panel of specialists will form a technical committee for guiding the project. Variables will be identified which define national and regional goals, specify the connectives between these goals and water-related activities in the 11 western states, and quantify these connectives. Important resource constraints will be analyzed to achieve consistency in the model framework, and estimate the

degree of substitution between alternative goals given the physical, institutional, and political fabric of western water resources.

Principal Investigators: **D. F. Peterson, H. Caulfield**

Discipline Involved: **Political Science**

Sponsor: **Utah State University**



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

OBJECTIVES

1. To determine the economic interrelationship between the major sectors of Colorado's economy.
2. To estimate future output of specific sectors and determine the impact of these output changes on all sectors of Colorado's economy.
3. To delineate the economic importance of water resources on major sectors of Colorado's economy.
4. To estimate the economic impact of assumed water resource changes on Colorado's economy within both a positive and normative framework.

APPROACH

Input-output analysis will be used to accomplish objectives 1, 2, and 3. Objective 4 will combine elements of normative analysis with the positive analysis of the input-output model.

Principal Investigator: **S. L. Gray**

Discipline Involved: **Economics**

Sponsors: **OWRR, CSU Experiment Station, Colorado Water Conservation Board**



Finance in Public Water Resource Use and Development (OWRR-A-015-COLO)

OBJECTIVES

1. To conceptualize the domain of "finance" in relation to water use and development.
2. To identify research completed or underway relating to finance.
3. To appraise the depth and significance of its main concern and the coverage of the domain by all identified research.

4. To undertake an appraisal of the application in Colorado since 1965 of the cost-sharing provisions of the Federal Water Projects Recreation Act of 1964, and an appraisal of alternative methods of financing federal irrigation works in the light of experience of federal reclamation projects in Colorado.

APPROACH

The Federal Water Projects Recreation Act of 1964 will form a basis for part of this study. An analysis of its legislative history will identify the policy intentions of its cost-sharing provisions. Certain Colorado projects will be selected for detailed study to determine relationships between implementation practices and policy intent. Federal reclamation projects in Colorado will be used as case studies with regard to financing methods, alternatives that could be used, problems of financing under law, etc.

Principal Investigators: **H. P. Caulfield, R. Young**

Disciplines Involved: **Political Science, Economics**

Sponsor: **OWRR**



**Institutions for Metropolitan Water Resources
Planning, Development, and Management**

OBJECTIVES

To identify literature on institutions and institutional processes, particularly that concerned with urban-metropolitan water resources planning, development, and management. A major task of the project will be the definition of institutions in operationally useful terms, and relating literature, experience, and practice with respect to urban-metropolitan water planning, development, and management to such definitions.

APPROACH

An examination will be made of the general literature on institutions and institutional processes which may provide analogues for urban-metropolitan water situations. Literature dealing with "nonwater" institutions will also be examined since such institutions may often impinge on water policies and practices, and constrain or shape approaches to urban-metropolitan water problems.

The development of socio-political and behavioral concepts and ideas with respect to institutions and institutional processes will be reviewed and evaluated. Attention will be directed to the formation and evolution of institutions; their roles and functions in shaping societal

attitudes, values, and norms, and in social control with respect to water.

Principal Investigator: **N. Wengert**

Discipline Involved: **Political Science**

Sponsor: **OWRR**



**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**

Sponsors: **OWRR, CSU Experiment Station**



The Value of Water in Alternative Uses

OBJECTIVES

To develop a conceptual framework for determining the value of water when used for purposes of irrigation, domestic water supply, industry, hydroelectric power generation, waste land dispersion, navigation, fish and wild-life habitat and recreation, and to make estimates of the marginal and total value of water in these uses for different regions of the United States.

APPROACH

The evaluation of water in alternative uses calls for the application of the body of economic theory which prescribes the conditions necessary for the optimal allocation of resources. Water is often allocated outside the market in many instances. Valuation procedures in the absence of market prices were developed by techniques which depended on the determination of measures of the willingness-to-pay of user groups.

Principal Investigators: **R. B. Reid, R. A. Young, S. L. Gray, L. M. Hartman**

Discipline Involved: **Economics**

Sponsor: **National Water Commission**

WATER SUPPLY AUGMENTATION AND CONSERVATION



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**

Sponsor: **USDI-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**

Sponsor: **USDI-Bureau of Reclamation**



Hydraulics of Surface Irrigation

OBJECTIVES

1. 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: **W. E. Hart, Norman A. Evans**

Discipline Involved: **Agricultural Engineering**

Sponsor: **CSU Experiment Station**



Irrigation Water Efficiency

OBJECTIVES

To evaluate the influence of amount and timing of irrigation on crop development, total consumptive use, crop yield, and irrigation efficiency in order to develop practices for maximum production from limited supplies of water.

APPROACH

Irrigation treatments will be used in field studies to establish various levels of soil water availability at specific periods of crop development. Plant growth processes and water use will be studied during the development periods and for the entire growing season. Instrumentation will be used to measure soil water changes, evapotranspiration, irrigation, and natural precipitation. Total seasonal water use and crop yields will be used to evaluate irrigation water efficiency as influenced by irrigation application practices.

Principal Investigator: **R. E. Danielson**

Discipline Involved: **Agronomy**

Sponsor: **CSU Experiment Station**



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 1-acre portion on each of three plots is clearcut.

Principal Investigators: **R. Dils, J. Meiman**

Discipline Involved: **Watershed Science**

Sponsor: **USDI-Bureau of Reclamation**



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 mathematical 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**

Sponsor: **CSU Experiment Station**