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HYDRAULIC RESEARCH
at
COLORADO STATE UNIVERSITY

Compiled by
M. M. Skinner

Prepared for the 1964 issue of
"Hydraulic Research in the United States"
National Bureau of Standards

Civil Engineering Section
Colorado State University
Fort Collins, Colorado

December 1963

CER63MMS65

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INTRODUCTION

This is a summary of research projects which are underway, or which have been completed since December 1962.

REPORTING ORGANIZATION

The reporting organization is the Civil Engineering Section, Colorado State University, Fort Collins, Colorado. Dr. J. W. N. Fead is Acting Head, Civil Engineering Department and Dr. D. B. Simons is Acting Chief, Civil Engineering Research Section. Reporting units included in this report are The Civil Engineering Section, The Department of Atmospheric Science, The Colorado Agricultural Experiment Station, The Agricultural Engineering Department, The U.S. Department of Agriculture - Soil Conservation Service, The U.S. Geological Survey and The Agricultural Research Service.

FORMAT

The following format is used in this report:

- (a) Title of project.
- (b) Name of organization for which the work is being done.
- (c) Name and title of person to whom a request for further information should be addressed. The address in every case is: Civil Engineering Section, Colorado State University, Fort Collins, Colorado.
- (d) Nature of the project: (1) Experimental, theoretical, or field investigation, and (2) whether it is classified as basic research, applied research, design, operation, development, for thesis (master's, doctoral), or otherwise.
- (e) A brief description of the project.
- (f) Present status.
- (g) Results.
- (h) Publications.

The above format follows that used in the publication, "Hydraulic Research in the United States," prepared annually by the National Bureau of Standards. The numbers preceding some of the titles of the projects were the numbers assigned by the National Bureau of Standards in previous publications.

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PROJECTS

(55) SNOW COURSE MEASUREMENTS AND FORECAST ANALYSIS

- (b) Soil Conservation Service, Colorado Agricultural Experiment Station.
- (c) Mr. Jack N. Washichek, Snow Survey Supervisor, Agricultural Engineering Section.
- (d) Field investigations; applied research.
- (e) Systematic measurements of depth and water content of snow are being made at high elevations in Colorado and New Mexico mountain areas for the purpose of forecasting the runoff of the principal rivers in the interest of irrigation, power, domestic supplies, and other uses. The use of electrical resistance soil moisture units is being tested to determine a factor of soil moisture deficiency for water supply forecast purposes. Most of the major basins now have two or more soil moisture stations installed. Correlation of soil moisture and runoff is now being developed with the hope that this information can be used as a factor in forecasting.
- (f) Active.
- (g) Forecasts are now being issued at forty-four gaging stations in Colorado and New Mexico. As forecast procedures improve, additional streams will be forecasted and other areas of potential power and irrigation development will be investigated on the Colorado, San Juan, Animas and Arkansas Rivers.
- (h) Colorado Agricultural Experiment Station General Series Papers Nos. 780, 781, 782, and 783 covering monthly snow reports for all of Colorado and New Mexico.

Nine small basin reports and one two-state bulletin covering the South Platte River watershed; Arkansas River watershed; Rio Grande watershed in Colorado; Rio Grande watershed in New Mexico; Dolores River watershed; San Juan and Animas River watershed; Gunnison River watershed; Colorado River watershed; Yampa, White and North Platte River watershed; Lower South Platte River watershed. Supplemental reports are issued January 1, May 15, and June 1.

A summary of all back data was issued this fall.

A bulletin entitled "Snow Surveys in Colorado" will be ready for distribution in December. This is co-authored by Norman A. Evans, Homer J. Stockwell and Jack N. Washichek.

(821) GROUND WATER FLUCTUATIONS AND THEIR RELATION TO PUMPING

- (b) Colorado Agricultural Experiment Station.
- (c) Mr. M. M. Skinner, Assistant Civil Engineer.
- (d) Field investigation; applied research.
- (e) Semi-annual measurements of the depth to the water table in approximately 610 observation wells are presently being obtained. The Ground Water Branch of the U.S. Geological Survey, Denver, Colorado are co-operating in furnishing measurements for about 130 wells. The observation wells are primarily existing irrigation wells in the South Platte and Arkansas River Basins, the High Plains area of eastern Colorado and the San Luis Valley. Electrical Power and Natural Gas Consumption data are compiled and estimates of ground-water pumpage made. The purpose of the project is to detect areas of ground-water depletion, to develop

relationships between gross pumpage and respective ground-water reservoir storage volume changes, and acquire basic data for ground-water studies in the various areas of Colorado.

- (f) Active.
- (g) Ground-water levels of the spring of 1963 are generally steady to down slightly as compared to the spring of 1962 in the South Platte and Arkansas River Basins and the San Luis Valley. Considerable ground-water pumpage is continuing in the High Plains area of eastern Colorado with some increase in pumping lifts resulting. Reported electrical power consumption by electrical pumping during 1962 in Colorado amounted to approximately 104,000,000 kilowatt hours for 8653 pumping units.
- (h) "Colorado Ground-Water Levels - Spring 1962," by M. M. Skinner, Colorado State University Experiment Station, Civil Engineering Section, Fort Collins, Colorado.
 "Summary of Electrical Power and Natural Gas Used by Irrigation Pumps in Colorado During 1962 as Reported by Power Companies," by M. M. Skinner, Colorado State University, Civil Engineering Section, Fort Collins, Colorado.
 "Artificial Ground-Water Recharge Operations in Prospect Valley," by M. M. Skinner. Progress Report No. 89, June 1963.
 "Ground-Water Table Fluctuations in Colorado," by M. M. Skinner. Progress Report 90, June 1963.
 "Water Resource Management in the Prospect Valley Area, Colorado," by M. M. Skinner. CER63MMS40, September 1963.

(2514) ALLUVIAL CHANNEL HYDRAULICS

- (b) U.S. Geological Survey.
- (c) Mr. H. P. Guy, Acting Project Chief.
- (d) Laboratory investigation; basic research.
- (e) A laboratory study of resistance to flow, sediment transport and related problems in alluvial channels is being made.
- (f) Active.
- (g) Five different bed materials ranging in size from 0.19 millimeters to 0.93 millimeters have been studied. The forms of bed roughness which occur and their relation to sediment transport and resistance to flow have been studied and described. The effect of large concentrations of suspended fine sediment (clay), the viscosity of the water and the specific weight and gradation of the bed material on the mechanics of flow and on sediment transport in alluvial channels have also been investigated.
- (h) "A Study of Variables Affecting Flow Characteristics and Sediment Transport in Alluvial Channels," by D. B. Simons and E. V. Richardson, presented at the Federal Inter-Agency Sedimentation Conference, Jackson, Mississippi. January 28, 1963
 "Control Structures for Sand Bed Channels," by F. C. Stepanich, D. B. Simons, and E. V. Richardson, presented at ASCE Water Resources Conference, Milwaukee, Wisconsin. May 1963

(2760) METEOROLOGICAL OBSERVATIONS

- (b) Colorado Agricultural Experiment Station and U.S. Weather Bureau.
- (c) Mr. Lewis O. Grant, Associate Research Engineer.
- (d) Field investigation; basic research.

- (e) Meteorological observations are being obtained to establish long-term records of climatological elements and to support current experiment station research which is weather dependent. The elements observed are: Maximum and minimum temperature and wet and dry bulb temperatures at 3, 6, 12, 24, 36, and 72 inches; wind direction and velocity at 15 inches and 65 feet above ground; barometric pressure; evaporation from a free water surface; surface water temperature; precipitation; cloud cover; dew and frost.
- (f) Active.
- (g) Complete meteorological observations have been made throughout the year.
- (h) "Meteorological Observation," by Lewis O. Grant. Progress Report No. 107, August 1963
 "The Role of Dew and Frost in the Water Balance of the Plains and Mountains of Colorado," by L. O. Grant and W. E. Marlatt. Progress Report No. 109, August 1963.

(2770) TURBULENCE STUDIES IN LIQUID USING ELECTROKINETIC PHENOMENON

- (b) National Science Foundation.
- (c) Dr. J. E. Cermak, Professor of Engineering Mechanics and Civil Engineering, and Dr. L. V. Baldwin, Associate Professor.
- (d) Experimental research; basic research, doctoral thesis.
- (e) The primary objective of the study is to determine the interaction between velocity fluctuations produced by turbulence in the liquid flow and electrokinetic potential fluctuations generated at a liquid-solid interface. Knowledge gained by this study will be applied to developing techniques for measuring turbulence characteristics in liquids.
- (f) Active.
- (g) Probes constructed with electrode pairs have been used to measure the distribution of turbulence intensities (three components) and the turbulent shear stress across a diameter of a circular pipe. The distribution measured in water agree with those obtained by Laufer in air using a hot-wire anemometer.
- (h) "Measurement of Turbulence in Water by Electrokinetic Transducers," by J. E. Cermak and L. V. Baldwin. December 1963.
 "Physics of Fluids," by G. J. Binder and J. E. Cermak. August 1963.

(2902) DEVELOPMENT AND IMPROVEMENT OF WATER MEASURING DEVICES

- (b) Colorado Agricultural Experiment Station and Northern Plains Branch, Soil and Water Conservation Research Division, ARS, USDA.
- (c) D. B. Simons, Acting Chief, Civil Engineering Section.
- (d) Experimental, laboratory investigation; applied research, operation and development.
- (e) New and improved devices and techniques for measurement of irrigation water are being developed. Specific objectives are (1) Design, evaluation and calibration of trapezoidal measuring flumes, (2) Evaluation of the constant head orifice farm turnout, and (3) Development of a probe using the drag on a suspended wire to indicate total flows, velocity distributions and forces on sediment particles.

- (f) Active.
- (g) The development of trapezoidal measuring flumes is continuing. Flumes with cross-sections corresponding to common slipform concrete ditches have been designed and calibrated.
Several forms of the constant head orifice farm turnout were evaluated during the year. Calibrations were verified and the reliability of measurement under different adverse operating conditions was determined. Alterations of the structure were developed to improve the accuracy of measurement.
The suspension wire probe has undergone further refinement, and development. It is being used to take precise measurements of the vertical velocity distribtuion in open channels which are being used to improve existing velocity distribution theories.
- (h) Discussion "Unification of Parshall Flume Data," by A. R. Robinson and Henry Liu. June 1962
"Conveyance, Control and Measurement of Irrigation Water on the Farm," by A. R. Robinson, C. W. Lauritzen, D. C. Muckel, and Jack Phelan. 1962
"Evaluation of the Vane-Type Flowmeter," by A. R. Robinson. January 1963
"A Flow Measuring Device Depending on the Drag Developed on a Wire Suspended in Water," by B. B. Sharp. December 1962.
"The Constant Head Orifice Farm Turnout," by E. Gordon Kruse. November 1962
"Control Structures for Sand-Bed Channels," by F. C. Stepanich, D. B. Simons, and E. V. Richardson. May 1963
"Control Structures in Alluvial Channels," by Frederick C. Stepanich. August 1962
"Flow Characteristics of Low Weir Structures in Alluvial Channels," by J. D. Lawson and D. B. Simons. April 1963.

(3034) DISTRIBUTION AND CONCENTRATION OF RADIOACTIVE WASTE IN STREAMS BY FLUVIAL SEDIMENT

- (b) U.S. Geological Survey for Atomic Energy Commission.
- (c) Mr. William W. Sayre, Project Chief
- (d) Experimental and theoretical; basic and applied research.
- (e) A significant fraction of the low level liquid radioactive wastes which are discharged into surface streams is often sorbed by bed material and fine material sediment particles. Consequently the manner in which these sediments are transported is a significant factor in determining the distribution of radioactive wastes in the stream environment. The project is devoted to investigating the dispersion and transport of both fine and bed material sediment particles. Experiments are being conducted in natural streams and in laboratory flumes. Radioactive tracer techniques, fluorometry and nephelometry are among the experimental techniques being employed. Analytically and experimentally the phenomenon of sediment transport is being treated from a Lagrangian point of view.

- (f) Active.
- (g) (1) The transport of bed material particles can be described as an alternating sequence of steps and rest periods in which the step lengths and rest period durations are exponentially distributed. In stochastic processes this would be known as a compound Poisson process. This yields a concentration distribution function which agrees with distributions of concentrations of radioactive tracer particles observed in the North Loup River, Nebraska, and in a laboratory flume. (2) Radioactive tracer techniques provide a feasible method for determining bed material discharge averaged over a period of time. (3) The longitudinal dispersion of dye and fine suspended sediment particles in a wide rectangular open channel with a rough boundary follows closely the prediction of the Taylor-Elder theory in which a virtual coefficient of longitudinal dispersion is computed using the velocity distribution and the Reynolds analogy concerning the equivalence of mass and momentum transfer. Also in such a channel, experiments to date indicate that at large distances from the source the rate of lateral dispersion from a continuous point source is essentially constant over most of the flow depth.
- (h) "Transport and Dispersion of Labeled Bed Material, North Loup River, Nebraska," by W. W. Sayre and D. W. Hubbell, U.S. Geological Survey Open File Report. April 1963.
 "Application of Radioactive Tracers in the Study of Sediment Movement," by D. W. Hubbell and W. W. Sayre. February 1963.
 "Uptake and Transport of Radionuclides by Stream Sediments," by W. W. Sayre, H. P. Guy and A. R. Chamberlain. 1963.
 "Transport of Radionuclides in Fresh Water: Dispersal of Bed Sediments," by W. W. Sayre and D. W. Hubbell. July 1963

(3395) **FUNDAMENTAL STUDY OF A SUBMERGED THREE-DIMENSIONAL JET IMPINGING UPON A NORMAL PLANE**

- (b) National Science Foundation.
- (c) Mr. George L. Smith, Civil Engineering Section, Colorado State University, Fort Collins, Colorado.
- (d) Experimental and theoretical; basic research and graduate thesis.
- (e) A study was made of an axisymmetrical jet of air impinging normally on a flat smooth plate. The mean velocity, the turbulent intensities and the turbulent shear stress were measured by means of a hot-wire anemometer in order to study the decay of the mean velocity, the growth of the boundary-layer thickness and the turbulent structure. A sensitive floating-element type shearmeter was designed and used. Data on skin friction obtained by direct shear measurements may be used to predict the distribution of the skin friction in similar wall jets. The objective of the program was to investigate systematically the effects on jet flow of the interaction between the free boundary and the solid boundary of varying roughness and configuration.
- (f) Completed.
- (g) The characteristics of the whole boundary-layer is dominated by the effect of the free jet, and the wall influences the flow only in a very limited region close to the wall. This results in much higher turbulent intensities and turbulent shear stress which increases the wall shear stress for this flow case as compared to two-dimensional uniform flow over a flat plate and smooth pipe flow. The ratio of turbulent intensities

$$\sqrt{w'^2} / \sqrt{u'^2}$$

is in general not a constant across the boundary-layer which indicates non-applicability of Prandtl's assumption of u', w' for this case.

- (h) "Fundamental Study of a Submerged Three Dimensional Jet Impinging Upon a Normal Plane," compiled by G. L. Smith. June 1963.

(3398) TURBULENT DIFFUSION IN SHEAR FLOW

- (b) National Institute of Health, Public Health Service, U.S. Department of Health, Education and Welfare, Washington, D.C.
- (c) Dr. J. E. Cermak, Professor of Engineering Mechanics and Civil Engineering.
- (d) Experimental research; basic research, doctoral thesis.
- (e) The objective of this project is to determine the influence of geometrical factors (land surface roughness, topography and structures), and thermal and aerodynamical factors (turbulence intensity and scale) upon atmospheric diffusion of heat and mass. "Laws of modeling" or similitude parameters" are sought by obtaining detailed data under various conditions in the wind tunnel and by comparing them with similar data now existing for the atmospheric prototype.
- (f) Active.
- (g) Application of a hypothesis of Lagrangian similarity to particle motions in a turbulent shear flow near a solid boundary has yielded similarity parameters and relationships between them which correlate the wind-tunnel diffusion data and available diffusion data obtained in the atmospheric surface layer.
- (h) "Wind Tunnel Modelling of Atmospheric Diffusion," by R. C. Malhotra and J. E. Cermak. April 15, 1963

(3400) HYDRAULICS OF SUB-CRITICAL FLOW IN SMALL, ROUGH CHANNELS

- (b) Colorado Agricultural Experiment Station and Agricultural Research Service, U.S. Department of Agriculture.
- (c) Mr. Norman A. Evans, Agricultural Engineer.
- (d) Theoretical; laboratory experiment.
- (e) Both laboratory and field studies have been conducted. A tilting flume was used in the laboratory, and a portable truss to carry a measuring carriage was used in the field. The purpose is to relate roughness in small channels to flow resistance.
- (f) Active.
- (g) Resistance to flow in small channels does not follow the same relationships established for large channels. The standard deviation of peak to valley heights was found to be a significant parameter, and a spectral density description of roughness is being tested.
- (h) "Hydraulics of Surface Irrigation," by Norman A. Evans. 1962 (Also, see No. 4296 under U.S.D.A.-ARS Section in National Bureau of Standards publication "Hydraulic Research in the United States.")

(3696) STUDY OF CLOUDS AND SNOWFALL IN THE ROCKY MOUNTAINS, AND CHANGES RESULTING FROM THE ADDITION OF ARTIFICIAL ICE NUCLEI

- (b) National Science Foundation and The Climax Molybdenum Company.
- (c) Mr. Lewis O. Grant, Associate Research Engineer.
- (d) Field investigation; basic research, applied research.
- (e) Various physical factors important in "Cold Cloud" orographic precipitation processes are being investigated under winter-time conditions in the high mountains of Colorado. This includes observations of airflow over the mountains, the characteristics of the "cold" orographic clouds rising over the nuclei, the characteristics of individual snow particles falling from these clouds, snow water freezing characteristics, snowfall amounts, and the changes in these conditions when artificial ice nuclei are supplied.
Large kites are being developed to serve as an instrumentation platform at elevations up to about 4000 ft above mountain top levels. Observations will include temperature; humidity; horizontal and vertical components of wind; cloud water droplet and ice crystal size, concentration and shape, and ice nuclei concentration.
- (f) Active.
- (g) Field equipment and procedures for use at high elevations in the Colorado Rockies have been developed. Observations of the daily accumulation of snowfall, atmospheric ice nuclei, and various other cloud and snow characteristics have been made over a large area for seeded and unseeded days during two winter seasons. Significant increases in ice nuclei have occurred in the area of the observation network on a number of the "seeded" days. The sample size is to be increased before attempting to determine the statistical significance of this apparent increase in snowfall.
- (h) "Cloud Seeding for Increasing Mountain Snow Cover," by Lewis O. Grant. Progress Report No. 108. August 1963.
"Indications of Residual Effects from Silver Iodide Released into the Atmosphere," by Lewis O. Grant.

(3697) MEASUREMENT OF ATMOSPHERIC OZONE WITH THE DOBSON SPECTROPHOTOMETER

- (b) Air Force Cambridge Research Center, L. G. Hanscom Field, Bedford, Massachusetts.
- (c) Mr. Lewis O. Grant, Associate Research Engineer.
- (d) Basic research.
- (e) Measurements of the total amount and the vertical distribution of ozone with height are being made with the Dobson Spectrophotometer. Direct measurements of the vertical distributions of ozone are being made to around 100,000 ft utilizing an ozone sonde. Daily amounts of total ozone are being related to atmospheric circulation patterns.
- (f) Active.
- (g) Observations of total ozone and the vertical distribution with height have been made on a regular basis for days when sky conditions have been clear.
- (h) Observational data are being supplied to the U.S. Weather Bureau for publication. Reports are submitted to Air Force Cambridge Research Center.

(3704) DEVELOPMENT AND USE OF COLORADO BENTONITE IN SEALING IRRIGATION CANALS AND RESERVOIRS

- (b) State of Colorado
- (c) R. D. Dirmeyer, Jr., Project Leader
- (d) Field investigation; applied research and development.
- (e) The work consists of three stages: (1) Inventory of clay deposits in Colorado with emphasis on those potentially usable in sealing canals and reservoirs. (2) Laboratory evaluation of clays from (1) above. (3) Field trials in canals and reservoirs with best clays found in (1) and (2) and evaluation of sealing results (initial and with time).
- (f) Active
- (g) Inventory and Testing--In excess of 310 samples of Colorado clays have been collected and tested in the laboratory.
Development of Deposits and Field Trials--Eight deposits have been developed commercially. Clays from these deposits have been used in about 100 trials in canals and ponds during the past three years.
- (h) A final report of the three-year project is being prepared and is scheduled for completion by 1-1-64.
"Methods of Using Colorado Clays for Sealing Canals and Ponds," by R. D. Dirmeyer and M. M. Skinner. Progress Report No. 91. July 1963.
"Specifications for Colorado Clays for Sealing Canals and Ponds," by R. D. Dirmeyer. Progress Report No. 92. July 1963
"Sampling and Testing of Colorado Clays for Sealing Purposes," by R. D. Dirmeyer, G. A. Lutz and L. G. White. Progress Report No. 93. July 1963

(3708) INVESTIGATIONS TO DEVELOP WIND TUNNEL TECHNIQUES FOR MEASURING ATMOSPHERIC GASEOUS DIFFUSION IN MODEL VEGETATIVE SURFACES

- (b) Agricultural Research Service, U. S. Department of Agriculture.
- (c) Dr. J. E. Cermak, Professor of Engineering Mechanics and Civil Engineering; and Mr. E. J. Plate, Associate Professor.
- (d) Laboratory research; basic research, applied research for thesis (doctoral).
- (e) Diffusion of a gas (ammonia) into and out of a model vegetated plane area of a wind tunnel test section floor is to be studied. Using a test section 80 ft long and 6 x 6 ft in cross section the turbulent boundary layer in which diffusion occurs will be several times thicker than the vegetation height. Using the basic equations of fluid mechanics, an attempt will be made to establish criterion for application of the model data to prototype conditions. The criterion developed will be checked using field data being obtained at Cornell University by the Agricultural Research Service.
- (f) Completed.

- (g) A study of diffusion from a line source into a boundary layer over a flat, smooth plate has been completed. Results show that the diffusion pattern can be separated into different zones, according to distances from the source in which different similarity laws are valid for the diffusion process.
- (h) "Investigations to Develop Wind Tunnel Techniques for Measuring Atmospheric Gaseous Diffusion in Model Vegetative Surfaces," by E. J. Plate and J. E. Cermak. July 1963
"Effects of Flexible Roughness Elements on Diffusion in a Turbulent Boundary Layer," by Ali Akhtar Quraishi. December 1963.

(4098) HIGH LEVEL TURBULENCE

- (b) U.S. Navy Weather Research Facility, Building R-48, Naval Air Station, Norfolk, Virginia.
- (c) Dr. Elmar Reiter, Associate Professor.
- (d) Field investigation; basic research.
- (e) By means of stereo-photography of high-level clouds a study will be made of wave lengths of disturbances in the jet-stream region, which might account for clear-air turbulence. Case studies and theoretical studies of clear-air turbulence will be made.
- (f) Completed
- (g) Cameras have been calibrated and reduction procedures programmed for electronic computer.
- (h) "Turbulenz im wolkenfreien Raum (Clear-Air Turbulence) - ihre Beobachtung, ihre physikalische Beschaffenheit und ihre Bedeutung fuer Ueberschall - und Raketenflug," by Elmar R. Reiter. April 1963
"A Case Study of Radioactive Fallout," by Elmar R. Reiter. CER63ERR7
"Die Feinstruktur der freien Atmosphaere und ihre Messung," by Elmar R. Reiter. 1963
"A Case Study of Severe Clear-Air Turbulence," by Elmar R. Reiter. 1963
"Nature and Observation of High-Level Turbulence, especially in Clear Air," by Elmar R. Reiter. April 1963
"Occurrence and Causes of High-Level Turbulence," by Elmar R. Reiter, 1963. CER63ERR30

(4099) WAKE CHARACTERISTICS FOR BODIES OF REVOLUTION

- (b) Department of Navy, David Taylor Model Basin, Washington 7, D.C.
- (c) Dr. J. E. Cermak, Professor of Engineering Mechanics and Civil Engineering, and Dr. L. V. Baldwin, Associate Professor.
- (d) Experimental research; basic research, doctoral thesis.
- (e) A study will be made of the relations between axially symmetrical bodies and the wakes produced by them for varying mean velocities and turbulence levels of the mean flow, both with and without momentum addition by means of a jet directed downstream from the body. Basic data will be obtained for establishing similarity criteria for turbulent and mean flow characteristics at large distances downstream from the body.
- (f) Active.

- (g) The general character of the axial-symmetric wake has been investigated. Detailed study of spectra-analysis and turbulence energy decay along the wake axis has been performed.

(4100) ANALYSIS OF RIVER FLOW SEQUENCE

- (b) National Science Foundation
- (c) Dr. V. M. Yevdjevich, Professor of Civil Engineering
- (d) Theoretical; basic research.
- (e) The study of fluctuations of river flow and precipitation on an annual basis is in final stage. Monthly flows and monthly precipitation are being gathered for the study of fluctuation on a monthly basis. The first approach to a stochastic analysis of continuous time series of flow and precipitation has been initiated.
- (f) Active.
- (g) Fluctuations of flow and precipitation on an annual basis as stochastic process may be approximated by simple auto-regressive schemes.
- (h) "Fluctuations of Wet and Dry Years," Part I, Research Data Assembly and Mathematical Models, by Vujica M. Yevdjevich. 1963
"Patterns in Sequence of Annual River Flow and Annual Precipitation," by Vujica M. Yevdjevich. 1963

(4101) UNSTEADY FREE SURFACE FLOW IN A LARGE STORM DRAIN

- (b) U.S. Bureau of Public Roads and U.S. Public Health Service.
- (c) Dr. V. M. Yevdjevich, Professor of Civil Engineering.
- (d) Experimental and theoretical; basic research.
- (e) A 825-ft long, 36-in. diameter conduit, movable on 43 supports on a hillside, is used as the main experimental facility to simulate and record free surface waves in pipes. The same waves are computed by using a digital computer and then a comparison is made. The ultimate purpose is a development of a set of routing methods to suit the desired accuracy and the quality of the initial and boundary data. The experimental part of the hydraulic study is underway and in 1963 the measurements of velocity distributions and resistance factors in a partly full conduit have been carried out.
- (f) Active
- (g) The analytical study for directing the research is being completed.

(4102) WIND FORECASTING TECHNIQUES

- (b) Federal Aviation Agency, Federal Aviation Facilities Center, Atlantic City, New Jersey, Attn: RD-140.
- (c) Dr. Elmar Reiter, Associate Professor.
- (d) Theoretical, experimental; basic and applied research.
- (e) Automatic forecasting techniques for high-level winds which can be used by an automatic air traffic control system shall be devised and tested.
- (f) Completed.
- (h) "Note on the Eddy Kinetic Energy Distribution in Relation to the Jet Stream," by Elmar R. Reiter. CER62ERR68

(4106) GROUND WATER RESERVOIR MANAGEMENT

- (b) Colorado Agricultural Experiment Station and Colorado Water Conservation Board with U.S. Geological Survey also participating under contract with Colorado Water Conservation Board.
- (c) M. W. Bittinger, Associate Civil Engineer.
- (d) Theoretical and field investigations, applied research.
- (e) It is the purpose to study the operating characteristics of ground water reservoirs in Colorado. Specific studies include (1) the interrelationships of ground and surface water in alluvial valleys, (2) natural recharge from ephemeral streams, and (3) artificial recharge possibilities in the High Plains of Colorado.
- (f) Active.
- (g) (1) Studies indicate a significant change in phreatophyte growth affecting surface-ground water relationships in the Arkansas Valley of Colorado. Mathematical models have shown importance of priority of rights, aquifer characteristics, ground water pumping and consumptive demand on management of an integrated surface-ground water system. (2) Data collection in Kiowa Creek has continued--showing influence of stream losses on ground water levels. (3) Rainfall-runoff measurements in Playa-Lake watersheds has continued.
- (h) "A Study of Phreatophyte Growth in the Lower Arkansas River Valley of Colorado," by Morton W. Bittinger and Glen E. Stringham. April 1963.
 "Water on the High Plains of Eastern Colorado," by Robert A. Longenbaugh. Progress Report No. 72. June 1963
 "Phreatophyte Growth in the Arkansas River Valley of Colorado," by Morton W. Bittinger. Progress Report No. 70. June 1963.
 "Natural Ground-Water Recharge from Kiowa Creek," by Robert A. Longenbaugh, Morton W. Bittinger and Edmund F. Schulz. Progress Report No. 88. June 1963
 "Interrelationships of Surface Water and Ground Water," by Morton W. Bittinger. Progress Report No. 104. August 1963
 "Problems of Conjunctive Use of Surface Water and Ground Water Supplies," by Morton W. Bittinger. August 1963
 "The Problem of Integrating Ground Water and Surface Water Use," by Morton W. Bittinger. October 2, 1963
 "Ground and Surface Water Relationships Studied by Statistical Techniques," by Robert A. Longenbaugh and Morton W. Bittinger. December 1963
 "Natural Ground Water Recharge from Kiowa Creek, 1962 Progress Report," by R. A. Longenbaugh. February 1963

(4108) WATERSHED HYDROLOGY

- (b) Colorado Agricultural Experiment Station.
- (c) Dr. V. M. Yevdjovich, Research Hydraulic Engineer.
- (d) Theoretical and experimental; basic research.
- (e) The research is concerned with floods from small watersheds. It is being pursued in three phases: (1) Assembly of research data from actual floods on small watersheds, (2) Physical experimental studies on a large rainfall-runoff simulation platform, and (3) Theoretical studies of the relation between flood hydrographs and the rainfall and catchment factors that affect them.
- (f) Phase One is active, data collection having been commenced, Phase Two is active in the planning stages, and Phase Three is active in the very initial stage.

- (h) "Research Data Assembly for Small Watershed Floods," by E. M. Laurenson, E. F. Schulz, and V. M. Yevdjovich. September 1963.
"Floods from Small Watersheds," by V. M. Yevdjovich and E. M. Laurenson. Progress Report No. 71. June 1963.

(4110) TURBULENT AIR MOTION IN THE HIGH ROCKIES IN RELATION TO THE WATER YIELD OF UPPER WATERSHEDS

- (b) Colorado Agricultural Experiment Station.
- (c) Dr. Herbert Riehl, Professor of Atmospheric Science.
- (d) Field, basic and applied.
- (e) The structure of the turbulent wind eddies, which produce the exchange of momentum between atmosphere and ground in the high mountains, is unknown. Yet these have sufficient force for the most part to blow the snow away from the mountain slopes above timberline. This snow in part drifts into high-altitude basins where it accumulates in depth augmenting the summer water supply; in part it drifts on slopes where it readily evaporates. Much interest has been shown in the possibility of channeling the drift so that a substantially higher fraction goes into the basins. Technologically this appears to be feasible. But any construction is dependent on knowledge of the turbulence spectrum, especially on the first day following snowfall. In order to determine this spectrum, a first installation containing electronic wind and temperature measuring instruments have been established above timberline in the Central Colorado Rockies.
- (f) Field experiments starting in winter of 1963-1964.

(4112) THE DISCHARGE OF MAJOR WESTERN RIVERS IN RELATION TO THE GENERAL CIRCULATION OF THE ATMOSPHERE

- (b) Office of Naval Research, Department of the Navy.
- (c) Dr. Herbert Riehl, Professor of Atmospheric Science.
- (d) Basic research.
- (e) The discharge of major western rivers (Colorado, Columbia, Sacramento, Rio Grande) has fluctuations with the order of magnitude of the mean annual discharge itself. These fluctuations are brought about mainly by variations in precipitation yield and by variable evaporation. Heavy precipitation may result from seasonal conditions favorable for the recurrence of cyclones over headwater areas. High evaporation, requiring weeks of abnormally dry and warm conditions, must be a manifestation of general circulation anomalies of longer duration. The objective of the study is (1) to separate the "systematic" and "random" components of the precipitation, and (2) to determine the controls for the systematic anomalies of precipitation and evaporation.
- (f) Active.
- (h) "Precipitation Regimes Over the Upper Colorado River," by William Marlatt and Herbert Riehl. 1963
"Precipitation Episodes in the Upper Colorado River Basin," by Herbert Riehl and R. L. Elsberry. 1963
"Some Aspects of the Monthly Atmospheric Circulation Affecting Monthly Precipitation Over the Colorado River Basin," by James L. Rasmussen. 1963

(4113) WEATHER PATTERNS AND CIRCULATION OF THE TROPICS

- (b) U.S. Weather Bureau.
- (c) Dr. Herbert Riehl, Professor of Atmospheric Science.
- (d) Basic.
- (e) Part of the project deals with hurricanes, another part with general characteristics of weather in the tropics. Hurricane investigation is concerned (1) with the energy cycle of the mature storm, especially the role played by air-sea interaction in maintaining the center; (2) with the balance of forces in these storms and the nature and importance of frictional forces in a fully turbulent vortex; and (3) with the formative stage of hurricanes. Other studies are concerned with the variability of radiative emission from the atmosphere and with the interaction between tropical disturbances of less than hurricane intensity with their environment at large.
- (f) Active.
- (h) "Some Relations Between Wind and Thermal Structure of Steady State Hurricanes," by Herbert Riehl. February 1963
"On the Origin and Possible Modification of Hurricanes," by Herbert Riehl. September 1963

(4114) GRAVEL FILTER FOR TILE DRAINS

- (b) Colorado Agricultural Experiment Station.
- (c) Mr. Norman A. Evans, Agricultural Engineer.
- (d) Applied; experimental.
- (e) Gravels classed as "pit-run" meeting the criteria for sand filters previously established were used in cylinders simulating mole drains to determine the flow capacity of such drains.
- (f) Active.
- (g) Tortuosity is a significant geometric property of filter gravels as regards to their permeability.

(4115) INFLUENCE OF INORGANIC WATERSHED COVERS ON MOISTURE EXCHANGE IN A VERTICAL DIRECTION ACROSS THE SOIL-AIR INTERFACE

- (b) Colorado Agricultural Experiment Station, a contributing project of the Western Regional Research Project W-73.
- (c) Dr. A. T. Corey, Professor of Agricultural Engineering.
- (d) Applied and basic research.
- (e) This project is a study of the effects of inorganic covers (especially gravel mulches) on the hydrologic processes of evaporation and infiltration of moisture across the soil-air interface and the relationship of these processes to water yield.
- (f) Completed
- (g) It has been demonstrated by both laboratory and field experiments that gravel mulches substantially reduce the rate of evaporation from bare soils and promotes an increased accumulation of water in the soil.
- (h) A final report on this project is in preparation and will be published in "Hydrology Papers," Colorado State University.
"Influence of Inorganic Watershed Covers on Moisture Exchange in a Vertical Direction Across the Soil-Air Interface," Colorado Contributing Project, W-73, Progress Report No. 3, October 1963.

(4606) STRUCTURE OF TURBULENCE IN TURBULENT SHEAR FLOW

- (b) Department of the Army.
- (c) Dr. J. E. Cermak, Professor of Engineering Mechanics and Civil Engineering, and Mr. E. J. Plate, Associate Professor.
- (d) Experimental research; basic research, doctoral theses.
- (e) The effects of surface roughness and surface heating or cooling upon the structure of turbulence in boundary layer flow will be determined. The flows investigated will be those existing on the heated or cooled floor of a wind-tunnel test section 6 x 6 ft in cross section and 80 ft long. Space-time correlations, joint probability densities, spectra and intensities of the turbulent velocities and temperatures will be obtained by hot-wire techniques and special analog computers employing magnetic tape input.
- (f) Active.
- (g) A 2.5×10^{-5} inch diameter, 90% platinum-10% rhodium wire was evaluated as a resistance thermometer. From steady state evaluation of the wire physical properties the transient response of the wire was predicted. The predictions agree well with measured time constants for the wire. The bare wire with a detection current of 0.1 milliamps will have a sensitivity of approximately .07 millivolts per °F. The frequency response of the wire in still air is 3200 cycles per second and this increased to approximately 6000 cycles in a moving air stream of 100 feet per second.
- (h) "A Resistance Thermometer for Transient Temperature Measurements," by J. L. Chao and V. A. Sandborn. 1963

(4607) WIND-WAVE RESEARCH FACILITY

- (b) National Science Foundation and Colorado State University.
- (c) E. J. Plate, Associate Professor
- (d) Laboratory development and basic research of experimental nature.
- (e) The water surface configuration of concurrent water and air flow, as well as the structure of the velocity field in both water and air are measured. The measurements serve to verify or extend recent theories of wave generation by wind. At present, instrumentation is completed, and a data conversion system is being developed.
- (f) Active.
- (g) The construction was successfully completed.

(4608) TURBULENCE DATA ANALYSIS SYSTEM

- (b) Department of the Army and National Center for Atmospheric Research.
- (c) Dr. L. V. Baldwin, Associate Professor
- (d) Laboratory development.
- (e) The system employing magnetic tape input is designed to yield the following information: (1) spectra (10^{-3} to 10^4 cycles/second), (2) joint probability densities, (3) root-mean-squares, and (4) space-time correlation.
- (f) Active.

(4609) MODELING OF AIR-FLOW PATTERNS AT CANDLESTICK BALL PARK

- (b) Metronics Associates Inc., Menlo Park, California.
- (c) Dr. J. E. Cermak, Professor of Engineering Mechanics and Civil Engineering; and Mr. E. J. Plate, Assistant Professor.
- (d) Experimental; applied research.
- (e) The applied study utilizes a 1:800 scale model of the local topography and the Candlestick Ball Park Stadium placed in a 6 by 6 foot wind tunnel. Verification of the modeling technique is being accomplished as a first phase of the study by comparing model wind patterns with prototype wind patterns obtained by field measurements. The second phase of the model study will consist of modifying both topography and stadium to obtain minimum wind disturbance in the ball park.
- (f) Completed.
- (g) The first phase of the study has been completed with the result that model wind patterns have been found to be sufficiently representative of field behavior to permit proceeding to the second phase with confidence.
- (h) "Candlestick Park Wind Study Model Investigation, Vol. 1," by J. E. Cermak and R. C. Malhotra. July 1963

(4610) PREPARATION AND ANALYSIS OF CLIMATOLOGICAL DATA OF IMPORTANCE TO AGRICULTURE IN COLORADO

- (b) Colorado Agricultural Experiment Station, a contributing project of the Western Regional Research Project W-48.
- (c) Dr. A. T. Corey, Professor of Agricultural Engineering.
- (d) Applied.
- (e) This project has as its objectives: (1) to provide climatological data for a representative network of Colorado stations in a form suitable for weather analysis; (2) to obtain summaries of distributions of meteorological parameters pertinent to agriculture; (3) to devise and utilize statistical and computer methods for estimates of the probabilities of significant weather conditions; e.g., weekly rainfall totals and dates of critical spring and fall temperatures.
- (f) Continuing.
- (g) Work on objective 1 and objective 2 has been completed and work on objective 3 is in progress.
- (h) "Colorado Contributing Project, W-48, Progress Report No. 2," Colorado Agricultural Experiment Station. October 1963.

(4611) PERMEABILITY AND CAPILLARY PRESSURE RELATED TO MEDIA PROPERTIES

- (b) National Science Foundation.
- (c) Dr. A. T. Corey, Professor of Agricultural Engineering.
- (d) Experimental and theoretical basic research.
- (e) The study involves an investigation of a tentative theory describing how the functional relationship between relative permeability and relative capillary pressure is related to measurable properties of porous media.

- (f) Continuing, nearly complete.
- (g) A theory describing the interrelation between capillary pressure, liquid and gas permeability, and liquid saturation has been developed and verified experimentally. The results have been used to develop criteria for similitude in models for studying flow in partially saturated soils.
- (h) "Hydraulic Properties of Porous Media and Their Relation to Drainage Design," by R. H. Brooks and A. T. Corey. June 1963
 "Hydraulic Properties of Porous Media," by R. H. Brooks and A. T. Corey. December 1963
 (Also, see No. 4296 under U.S.D.A. - ARS Section in National Bureau of Standards publication "Hydraulic Research in the United States.")

(4612) TRANSPORT OF PARTICLES THROUGH UNSATURATED SOILS

- (b) Department of Health, Education, and Welfare, Bureau of State Service.
- (c) Dr. A. T. Corey, Professor of Agricultural Engineering.
- (d) Applied; experimental.
- (e) The objective of this research is to determine to what extent the transport of solid particles by water flowing through soil may be affected by the degree of saturation of soil. The term "soil" is interpreted broadly as including sands and gravels as well as agricultural soils. The solid particles to be considered in this study will be of sizes and shapes corresponding to that of viruses.
- (f) Active, continuing.
- (g) Work is still in a preliminary stage. Efforts to tag live virus particles with radioactive iodine without killing the virus has finally been successful.

(4617) MECHANICS OF LOCAL SCOUR

- (b) Department of Commerce, Bureau of Public Roads, Hydraulic Research Division.
- (c) Mr. S. S. Karaki, Associate Civil Engineer.
- (d) Theoretical and experimental; basic research.
- (e) A theoretical study of the mechanics of local scour is underway to develop basic equations for determining local scour. Basic experiments will be undertaken simultaneously to assist theoretical development.
- (f) Active.

TRANSPORT PROCESSES IN THE ATMOSPHERE LEADING TO RADIOACTIVE FALLOUT

- (b) Atomic Energy Commission, Washington, D.C.
- (c) Dr. E. R. Reiter, Associate Professor.
- (d) Theoretical; basic and applied.
- (e) Computations and case studies of transport processes carrying radioactive debris from the stratosphere into the troposphere have been made. Attempts have been made to arrive at seasonal estimates of radioactive fallout at the ground.
- (f) Active.

ARTIFICIAL CONTROLS FOR ALLUVIAL CHANNEL STREAMS

- (b) U.S. Geological Survey.
- (c) Mr. F. A. Kilpatrick, Project Chief.

- (d) Field investigation; applied research.
- (e) The basic stream flow data collection program of the U.S. Geological Survey for sand bed channels is in need of improvement. Such channels have unstable stage-discharge relationships. Thus effort is being made to develop control designs and construction methods suitable for alluvial channels. Methods for improving the stability will be designed and then tested in the laboratory and field. Careful consideration will be given to construction techniques in order to minimize costs of the data collection program.
- (f) Active.

CHANGE IN QUALITY OF DRAINAGE EFFLUENT FROM IRRIGATION PROJECTS USING A VISCOUS FLOW ANALOGY MODEL

- (b) U.S. Bureau of Reclamation.
- (c) M. W. Bittinger, Associate Civil Engineer
- (d) Experimental
- (e) The study is designed to determine quality change (with time) of tile drainage effluent under various aquifer and geometry conditions.
- (f) Active.

CUMULUS CONVECTION AND OROGRAPHIC CONVECTION CELLS

- (b) U.S. Army Electronics Research and Development Laboratory.
- (c) Dr. Herbert Riehl, Professor of Atmospheric Science and Mr. Montie M. Orgill, Jr. Meteorologist.
- (d) Basic and applied research.
- (e) The general goal of this research is to investigate various meteorological aspects of the monsoon circulations over Southeast Asia. Satellite, radar, surface and upper level observations will be utilized to examine such features as (1) the time of onset and retreat of the monsoon and its variability within the season; (2) macro- and mesostructure of cloud systems; (3) synoptic time sequence of the winds during the monsoon season, location of principal bad weather areas, their frequency and succession and; (4) the course of diurnal variations, especially precipitation.
- (f) Active.
- (h) "Cumulus Convection and Orographic Convection Cells," by Herbert Riehl. 1963
"Stationary Aspects of the Tropical General Circulation," by Herbert Riehl, June 1963

RANGE AND RUN CHARACTERISTICS OF NORMAL VARIABLE OF RANDOM SEQUENCE

- (b) National Science Foundation (Subproject of Analysis of River Flow Sequence)
- (c) Dr. V. M. Yevdjovich, Professor of Civil Engineering.
- (d) Experimental.
- (e) A random sample of 100,000 numbers has been generated. The distribution of range and adjusted range, a joint distribution of the mean and adjusted range for periods of length N as well as two types of runs have been studied by using a digital computer. Distributions and characteristics on distributions have been analyzed as benchmarks for study of flow and precipitation fluctuations.
- (f) Active.

FLOW MEASUREMENT

- (b) Colorado Agricultural Experiment Station and Civil Engineering Section.
- (c) Dr. D. B. Simons, Acting Chief, Civil Engineering Research Section.
- (d) Experimental laboratory and basic research which involves staff and graduate student participation leading to M.S. and Ph.D. degrees.
- (e) This project has the general objective of developing and improving devices and techniques for the measurement of irrigation water. The present activity includes: (1) the further development of the semi-conductor strain gage method of measuring velocity in pipes and open channels and its utilization to measure the velocity distribution above and very close to both smooth and rough boundaries in open channels and (2) continued studies of the trapezoidal measuring flumes, control structures for alluvial channels and other metering devices.
- (f) Active.
- (g) A suspension wire probe involving use of semi-conductor strain gages has been developed to measure average velocity in pipes and essentially point velocities in open channels. The probe is being further modified to measure velocity very close to boundaries.
- (h) "Evaluation of the Vane-Type Flowmeter," by A. R. Robinson, January 1963.
 "A Flow Measuring Device Depending on the Drag Developed on a Wire Suspended in Water," by Bruce B. Sharp. December 1962.
 "Control Structures for Sand Bed Channels," by F. C. Stepanich, D. B. Simons and E. V. Richardson. May 1963.

HYDRAULICS

- (b) Colorado Agricultural Experiment Station and Civil Engineering Section.
- (c) Dr. D. B. Simons, Acting Chief, Civil Engineering Research Section.
- (d) Basic hydraulic research.
- (e) This research is in hydraulics oriented toward agriculture and irrigation. The principal areas under study include, fall velocity, sediment transport, resistance to flow in alluvial channels with limited research on rigid boundary hydraulics including hydraulic jump phenomena in pipes and the design of stable alluvial channels.
- (f) Active.
- (g) A study has been completed on the fall velocity of porous media. Reports are in preparation on resistance to flow in open channels, bed material transport in open channels, and design of stable channels.
- (h) "Some Properties of Water-Clay Dispersions and Their Effects on Flow and Sediment Transport Phenomena," by W. L. Haushild, D. B. Simons, and E. V. Richardson
 "Some Properties of Water-Clay Dispersions and Their Effects on Flow," by D. B. Simons, E. V. Richardson, and W. L. Haushild.
 "A Study of Variables Affecting Flow Characteristics and Sediment Transport in Alluvial Channels," by D. B. Simons. January 1963
 "Closure to Depth-Discharge Relations in Alluvial Channels," by D. B. Simons, E. V. Richardson, and W. L. Haushild.
 "Fall Velocity of Artificial Porous Particles," by Komain Unhanand. 1963