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United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA. 22092

In Reply Refer To:
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June 12, 1981

Memorandum

To: Distribution

From: Deputy Assistant Chief Hydrologist, R&TC

Subject: PUBLICATIONS--Water Resources Research, FY 1980 Volume

Enclosed is the FY 1980 volume of Water Resources Research. The purpose of the volume is to improve the exchange of technical information between the National Research Program (NRP) of the Water Resources Division and other elements of the Division and the Bureau.

Distribution of the volume represents the culmination of efforts by staff members in Operations and R&TC as well as the individual efforts by researchers in the NRP. We will continue to work to improve the technical content and timeliness of future volumes.

I hope the volume is useful to you and provides you the kind of information that will support and enhance your own scientific investigations.

Roger G. Wolff

Enclosure

WATER RESOURCES RESEARCH
October 1, 1979—September 30, 1980

Summary statements of research activities
by the Water Resources Division

U.S. GEOLOGICAL SURVEY

WATER RESOURCES RESEARCH
October 1, 1979—September 30, 1980

Summary statements of research activities by the Water Resources Division

Compiled by the Office of the Assistant Chief Hydrologist for Research and Technical Coordination, Water Resources Division

U.S. GEOLOGICAL SURVEY

This report is intended primarily for use by the Geological Survey in program development, coordination, and review. Some of the progress summaries may include tentative results that must be tested further before they can be published. For this reason, the report should not be referred to in literature citations or other types of publications. The report is distributed only to members of the Survey staff, advisory committees of various kinds, and others having a special interest in development of water resources research.

Because there is no universally accepted definition for "research," certain of the Division's water resources investigations which appear in other subject-matter classifications have not been included in this volume.

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Doyle G. Frederick, Acting Director

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INTRODUCTION

Research in the WRD had its beginnings in the late 1950's when the "core research" line item was added to the Congressional budget. Since this time the Federal program has grown from a "basic sciences" program to one that includes a broad spectrum of basic and applied scientific investigations.

Water resources research in WRD includes the study of water in all its phases and uses the basic sciences of mathematics, chemistry, physics, biology, geology and engineering to gain a fundamental understanding of the processes that affect the movement of water and its chemical constituents through hydrologic systems. The basic knowledge and methodologies derived from water resources research are applicable not only to the solution of current problems associated with the Nation's water resources, but also to anticipated hydrologic issues.

The knowledge and methodologies gained from the Federal Water Resources Research Program have high transfer value to the operational program in WRD and the Geological Survey as well as to other public and private groups. Major programs of current study include: low and high level nuclear waste disposal, subsurface waste disposal, artificial recharge and regional aquifer analysis, coal and oil shale development, geothermal energy and volcanic areas hydrology. Areas of growing concern and study include acid rain, toxic substances in ground water systems and cold regions hydrology.

In addition, the Federal Water Resource Research Program supports other WRD programs by providing:

- Operational products (analytical methods, instrumentation for data collection and mathematical predictive models).
- A group of consultants and teachers available to the Division.
- A corps of hydrologic experts to the Division.

Water Resources Division Research
October 1, 1979 - September 30, 1980

This volume of Water Resources Research provides a brief overview of research activities in the Federal Water Resources Research Program for Fiscal Year 1980.

For the sake of technical management, the research program is divided into twelve research disciplines: water chemistry, geochemistry, solute transport, sediment, hydrogeology, ground water physics, unsaturated zone, surface water hydrology, surface water physics, snow and ice, ecology and socioeconomic studies.

The purpose of this volume is to provide a basis for improving the exchange of information between the National Research Program of WRD and other elements of the Division, Bureau, and Department. To do this a brief overview is provided for all projects in every research discipline. Several cross-indexes are provided to allow the reader to search topics of interest by project leader or key word.

The previous publication of Water Resources Research covered the period from July 1, 1975 - June 30, 1976. For the sake of continuity, the "completed reports" section includes reports published from July 1, 1976 through the end of FY 80 (September 30, 1980).

CR046 ORGANIC GEOCHEMISTRY

PROJECT TITLE: Quantification and characterization of Hydrophobic Organic Solutes in Water

WRD PROJECT NO.: CR 68-046

LOCATION: Topical Research

PROJECT CHIEF: MALCOLM, RONALD L.

HEADQUARTERS OFFICE: Arvada, CO

PROBLEM: Present techniques of organic solute fractionation of natural waters are qualitative and incomplete. Also the types or groups of organic compounds expected to be in certain reaches of background and contaminated streams is generally unknown.

OBJECTIVE: (1) To quantify organic solute fractionation by use of chromatographic expressions, original terminology, and mathematical equations. (2) To define differences in organic water quality as related to stream source and contamination.

APPROACH: (1) Quantification of hydrophobic-hydrophylic separation by use of column distribution coefficient, k'. (2) Correlation of k' with the ratio of carbon atoms to hydrophylic functional groups. (3) The effect of natural polyelectrolytes on the k' of simple organic solutes. (4) Evaluation of chemical, biological, geological, mineralogical, and hydrological processes which effect the origin, distribution and fate of various suites of hydrophobic organic solutes in natural waters.

PROGRESS AND RESULTS: Smectite clay and associated humic substances are responsible for fouling reverse osmosis (RO) membranes. Brominated fulvic acids rejected from passing through the RO membrane and concentrating in the RO brine reject are potentially hazardous chemicals in aquatic environments. The average molecular eight of aquatic fulvic acid is near 1000 as determined by low-angle x-ray scattering; this value is considerably smaller than previously reported. Three journal articles were written. Considerable time was spent in consulting and guest lecturing on organics in water. Evidence from reconnaissance stream sampling for humic substances continue to indicate that aquatic humic substances are different from soil humic substances.

COMPLETED REPORTS:

Aiken, G.R., Thurman, E.M., Malcolm, R.L., and Walton, H., 1979, Comparison of XAD macroporous resins for concentration of fulvic acid from aqueous solution, Analytical Chemistry, v. 52, pp. 1799-1803, 5 p.

Thurman, E.M., 1979, Conductivity detection of organic acids in reverse-phase chromatography: Journal of Chromatography, v. 185, p. 625-634

Thurman, E.M. and Malcolm, R.L., Preparative isolation of aquatic

humic substances: Director approved and submitted to Journal of Environmental Science and Technology, 5 p.

CR132 Organic polyelectrolytes

PROJECT TITLE: Behavior of natural polyelectrolytes in water

WRD PROJECT NO.: CR 68-132

LOCATION: Topical Research

PROJECT CHIEF: WERSHAW, ROBERT L.

HEADQUARTERS OFFICE: Arvada, CO

PROBLEM: Natural organic polyelectrolytes are highly active materials which are present in practically all natural water systems. They interact with both organic and inorganic pollutants, and in many instances, controlling the toxicity, rate of movement, persistance and rate of degradation of the pollutants in aquatic environments. Detailed knowledge of the chemistry of natural organic polyelectrolytes is therefore of primary importance in understanding the chemical changes that affect all of the components of natural water systems. Organic polyelectrolytes are eliminated from drinking water by coagulation and chlorination; however, the products of chlorination are not known.

OBJECTIVE: The objectives of the project are: (1) Isolation of the various organic polyelectrolytes present in natural water systems. (2) Determination of the physical and chemical properties of the most abundant organic polyelectrolytes. (3) Elucidation of the mechanisms of interaction of pollutants with natural organic polyelectrolytes. (4) Determination of types of chemical compounds that result from the chlorination of natural organic polyelectrolytes.

APPROACH: Our approach includes the following steps: (1) Isolation of chemically unique polyelectrolyte fractions using column chromatography, electrophoresis, and other techniques. (2) Determination of the physical and chemical properties of the fractions. (3) The use of carefully characterized organic polyelectrolyte fractions in experiments designed to elucidate the sorption, solubilization reaction of pollutants and nutrients with natural organic polyelectrolytes. (4) Application of the data obtained in step 3 to natural systems. (5) chlorination of various fractions and isolation and identification of products.

PROGRESS AND RESULTS: (1) A procedure has been developed for the differentiation of phenol, acid and carbohydrate groups in humic and fulvic acids by measuring the **13C nuclear magnetic resonance spectra of methylated samples. (2) The presence of a charge transfer complex in copper fulvic acid solutions has been established for the first time. (3) The radii of gyration of a number of different aquatic fulvic and humic acids have been measured by small angle x-ray scattering. (4) Our previously developed permethylation procedure has been improved by substituting sodium hydride for dimethyl sulfinyl carbanion. The new procedure givesm ore complete methylation than the old procedure.

COMPLETED REPORTS:

Wershaw, R.L. and Pinckney, D.J., 1978, Methylation of humic acid fractions: Science, v. 199, pp. 906-907.

Wershaw, R.L., Barofsky, D.F., and Barofsky, E., 1978, Field desorption mass spectrometry-Application to the elucidation of the structure of humic acid: Amer. Chem. Soc., National Meeting, Anaheim, Cal., Mar. 13-17, 1978, 1 p.

Wershaw, R.L., Pinckney, D.J., and Cary, L., Application of nuclear magnetic resonance spectroscopy to the chemical structure of humic acid: 20th Annual Rocky Mt. Conference on Anal. Chemistry, Denver, Colo., August 7-9, 1978, 1 p.

Wershaw, R.L. and Pinckney, D.J., 1978, Infrared spectra of permethylated humic acid fractions: 20th Annual Rocky Mt. Conf. on Analytical Chemistry, Denver, Colo. August 7-9, 1978, 1 p.

Wershaw, R.L., Pinckney, D.J., Barofsky, D.F., and Pankow, J.F., 1979, A new degradation procedure for the characterization of natural humic materials: Third Conference on Water Chlorination: Environmental Impact & Health Effects, 1979, 1 p.

McKnight, D.M. Feder, G., Thurman, E.M. and Wershaw, R.L., 1980, Interaction among copper, humic substances and hydrous metal oxides in streams: 34th Annual Meeting American Soc. Limnology & Oceanography, Knowville, Tenn., June 16-19, 1980, 1 p.

CR145 Methods for water analyses

PROJECT TITLE: Development of methods for analysis of Inorganics in Water and sediments

WRD PROJECT NO.: CR 59-145

LOCATION: Topical research

PROJECT CHIEF: Fishman, Marvin J.

HEADQUARTERS OFFICE: Arvada, CO

PROBLEM: Many published analytical methods require modification before they can be used for water analysis, such as the determination of nutrient materials, trace amounts of toxic metals, or the analysis of suspended and bottom-sediment materials. New and improved methods and instruments, including automated laboratory instrumentation, need to be developed, evaluated, and adapted. Constant development work is needed to improve analytical methods from the standpoint of sensitivity, reliability, and lower analytical costs.

OBJECTIVE: Apply fundamental chemical and physical principles to the development of methods for the solution of specific problems in water analysis. Continuously survey current scientific literature for developments which may either directly, or with suitable modification, provide improved methods and techniques for water analysis. Cooperate with other agencies in the standardization of methods and techniques for water-quality data acquisition.

APPROACH: Develop new analytical methods, and techniques for the solution of specific water-analysis problems. Modify, adapt, and improve both existing and newly-developed methods and instruments for particular applications in water-quality investigations, cooperate with other agencies and offices in the standardization of methods and techniques for acquiring reliable water-quality data.

PROGRESS AND RESULTS: Construction has been completed of a multielement atomic absorption spectrometer utilizing a diode array system. An ion chromatographic instrument has been automated by incorporating an autosampler and integrator. With the integrator, it is possible to lower the detection limits for a number of anions previously done manually. The automated system has been used to determine Cl, F, NO(3), NO(2), Br, PO(4), and SO(4) on leachates of Mt. St. Helens volcanic ash.

COMPLETED REPORTS:

Erdmann, D.E., Taylor, H.E., 1978, An automated procedure for the simultaneous determination of specific conductance and pH in natural water samples, v. 99, pp. 269-274.

Pyen, G.S., Fishman, M.J., 1978, Automated determination of selenium in water, v. 17, pp. 47-48.

Fishman, M.J., Erdmann, D.E., 1979, Water Analysis; Analytical

Chemistry, v. 51, p. 317R-341R, 24 p.

Pyen, G., Fishman, M.J., 1979, Automated determination of tin in water, Atomic Absorption Newsletter V. 18, p. 34-36, 3 p.

Taylor, H.E., Erdmann, D.E., 1979, An automatic range-switching modification for direct-reading specific conductance measurements, Chemical, Biomedical, and Environmental Instrumentation, V.9, p. 49-60, 12 p.

Spencer, R.R., Erdmann, D.E., 1979, Azomethine H colorimetric method for determining dissolved boron in water, Environmental Science and Technology, V. 13, p. 954-956, 3 p.

Skougstad, M.W., Fishman, M.J., 1978, Inorganic pollution in water -- The analyst's viewpoint, Toxicology and Environmental Chemistry Reviews, V. 2, p. 219-236, 18 p.

CR181 ORGANICS IN OIL SHALE RESIDUES

PROJECT TITLE: Sorption of waste organic solutes in retort waters by processed oil shale

WRD PROJECT NO.: CR 75-181

LOCATION: NW COLORADO, NE UTAH, SW WYOMING

PROJECT CHIEF: LEENHEER, JERRY A.

HEADQUARTERS OFFICE: Arvada, CO

PROBLEM: The various oil shale retorting processes produce 10-50 gallons of waste retort water per barrel of oil. This retort water contains 3,000-5,000 mg/l of dissolved organic carbon. Present plans are to dispose of this retort water on processed oil shale. Organic solutes may leach into ground water or run off into surface water if the sorptive capacity of the processed oil shale for waste organic solutes in retort water is unknown. There are no recommendations pertaining to the disposal capacity of processed oil shale for organic solutes in retort water.

OBJECTIVE: A preliminary objective will be to develop an organic water-quality analytical program such that the natural organic solutes found in surface and ground waters in regions of oil shale development can be characterized. The overall objective is to determine the capacity of processed oil shale to adsorb and immobilize waste organic solutes in retort waters. Both surface and in situ retorting processes will be studied.

APPROACH: Natural organic solutes in surface and ground water in regions of oil shale development and organic solutes in retort water will be characterized with respect to elemental composition, compound class, and physical-chemical properties. Processed oil shale adsorbents will be characterized with respect to surface area, elemental and mineralogical composition, surface chemistry, and saturating ions. Adsorption isotherms will be determined for retort water organic solutes on processed oil shale adsorbents. Adsorption kinetics will also be studied to determine adsorption mechanisms.

PROGRESS AND RESULTS: A study of soil-oil shale report water interactions was completed. Soil effectively removed ammonia and trace metals from retort water, but retort water extracted organic matter from the soil and altered its physical structure. A comprehensive scheme was developed for the preparative isolation and fractionation of 80-90% of organic solutes from oil shale retort waters and natural waters. The scheme was used to generate organic solute fractions from oil shale retort water for mutagenicity testing. A study of the selective isolation and fractionation of aromatic amines in retort water was completed. A chargeable weak-base resin used for adsorption followed by desorption with dilute acid gave the highest concentration factors.

COMPLETED REPORTS:

Casterline, C.E., and Leenheer, J.A., 1979, Determination of dissolved organic carbon in Methanol: American Lab v. 11, No. 5 pp 33-39, 7 p.

Leenheer, J.A., and Huffman, E.W.D., Jr., 1978, Analytical Method for dissolved-organic-carbon fractionation: U.S. Geol. Survey Water Resources Investigation, No. 79-4, 16 p.

Cowling, S.W., and MacCarthy, P., 1979, Evaluation of processed oil shale and sediments as sorbents for waste organic solutes produced by in situ oil shale retorting: Final report on U.S. Geol. Survey grant No. 14-08-0001-G-450 to the Colorado School of Mines, 124 p.

Stuber, H.A., and Leenheer, J.A., 1978, Assessment of a resin based fractionation procedure for monitoring organic solutes from oil shale retoring wastes. In "Establishment of water quality monitoring programs" (L.G. Everett and K.D. Schmidt, eds.), American Water Resources Association, to San Francisco, June, 1978, p. 266-272

Leenheer, J.A., 1980, Concentration, Partitioning, and Isolation techniques (for organics in water), Chapter III in Vol. III of Treatise on Water Analysis (R. Minear, Ed.) Academic Press New York, 60 p.

Leenheer, J.A., and Farrier, D.S., 1979, Applications of dissolved organic carbon fractionation analysis to the characterization of oil shale processing waters: EPA oil shale sampling, Ana. and Qua. Assur. Symposium, Denver, March, 79, 11 p.

CR199 Laser Spectroscopy

PROJECT TITLE: Laser Spectroscopy

WRD PROJECT NO.: CR 76-199

LOCATION: Topical Research

PROJECT CHIEF: Goldberg, Marvin C.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: To examine the chemical processes that occur in water by employing spectroscopic procedures that take advantage of the properties of laser light as an excitation source. The dissolved solutes, suspended and bed sediments and surface films are all subject to interrogation by selected light frequencies and will yield information regarding the occurrence, reactivity, longevity and chemical and physical interactions of these components of the hydrologic system. In this manner a definition of the chemical aspects of the hydrologic system can be obtained. Such information is a requisite for water use and water management.

OBJECTIVE: To develop instrumental techniques that qualify and quantify the dissolved and suspended solutes in the Hydrologic system. To further define the reactivity of the suspended materials surfaces, as rate controlling elements in the appearance and disappearance of solutes, and to relate these factors such that the controlling chemical factors in the hydrologic system are understood.

APPROACH: Suspended materials in water will be illuminated with polarized coherent light from a helium-neon laser. The scattered radiation in the forward lobe and the depolarization ratios in the backward lobe will be examined and correlated with particle concentration and size.

PROGRESS AND RESULTS: Sediment particles from less than 1 to 70 microns were measured by a laser light scattering technique. The instrumentation and methodology was developed and evaluated as regards resolution, sensitivity and precision. A laser light scattering sediment sensor capable of measuring particles for less than 1 to 1000 microns at concentrations ranging from less than 50 to more than 5000 ppm with reasonable precision has been developed. Surface coatings of goethite were synthesized onto quartz both in the crystalline and amorphous forms. Examination of these coatings was accomplished with Fourier Transform Infrared spectrography and photomicrography. Sorption desorption studies with phosphate showed no change between goethite coatings on silica and crystalline goethite. A technique for compensation of laser power fluctuations during the taking of Raman spectra was worked out. This technique appreciably enhances signal to noise levels.

COMPLETED REPORTS:

Goldberg, M.C. and Asting, Neil, 1978. Evaluation of Differences in Scattered Radiation caused by Excitation Wavelength Shift. (Abst.)

Lasers 1978, Orlando, Florida. December 14, 15, 1 p.

Goldberg, M.C. and Weiner, E.R., 1980, Extraction and Concentration of Phenolic Compounds from Water and Sediment ANALYTICA CHIMICA ACTA, v. 115, pp. 373-378

Cunningham, K.M. and Goldberg, M.C., 1979, A Technique for the Compensation of Laser Fluctuations in Raman Spectroscopy; LASERS 79, Dec. 17-21, Orlando, Florida (Abs.), 1 p.

Boymel, Paul, Goldberg, M.C. and Weiner, E.R., 1980, Sorption of Phosphate on Crystalline Goethite and Goethite Coatings on Silica: 22nd Rocky Mt. Conference on Analytical Chemistry and Spectroscopy, Aug. 11-14, Denver, CO., 1 p.

CR214 Development of Water Methods

PROJECT TITLE: Methods to Understand Transport of Metals by Sediment

WRD PROJECT NO.: CR 77-214

LOCATION: Topical Research

PROJECT CHIEF: Malo, Bernard A.

HEADQUARTERS OFFICE: Arvada, CO

PROBLEM: In order to evaluate or calibrate sediment-metal load transport models, it is necessary to identify and perform semi-qualitative measurements of the chemical mechanisms by which metals are transported in the hydrologic environment when associated with sediment.

OBJECTIVE: To develop analytical methods for water-sediment samples and bottom material samples that will define the forms in which metals are present when associated with sediment. Developed methods are to be amenable to use in devising sediment-metal load transport models.

APPROACH: Employ x-ray spectrometry, in conjunction with scanning electron microscopy and statistical techniques to qualitatively determine the metals present at the surface of sediment particles, their chemical form and relative abundance, and the composition and structure of the particles. Correlate results with conventional metal and mineralogic analytical techniques. Initial phase will be the evaluation of available techniques and preparation of a planning report.

PROGRESS AND RESULTS: Preliminary results from one of the three contract laboratories involved in the instrument and technique evaluation study indicate that the surface analysis techniques have the potential for providing useful chemical information, particularly on the valence state and associated ions, on sorbed metals. Problems associated with sample preparation and charging have been observed.

COMPLETED REPORTS:

Malo, B.A., Beetem, W.A., Friedman, L.C., Erdmann, D.E., The Quality Assurance Program of a National Laboratories System, 4th Joint Conference on Sensing Environmental Pollutants, ACS, 3 p.

Malo, B.A., An Overview of the U.S. Geological Survey's Quality-Assurance Program for Water Quality, Joint APCA/ADQC Conference-Quality Assurance in Environmental Measurements, 5 p.

CR216 Organic Chem. of Shale and Sediment

PROJECT TITLE: Origin, Fate, and Transport of Organic Pollutants Associated with Energy-related Substrates, and their Effect on Water Quality

WRD PROJECT NO.: CR 77-216

LOCATION: Topical Research

PROJECT CHIEF: Pereira, Wilfred E.

HEADQUARTERS OFFICE: Arvada, CO

PROBLEM: Spent shale is known to contain potentially hazardous organic co pounds which are present in concentrations several orders of magnitude higher than normally encountered in a pristine environment. These compounds can be leached from the carbonaceous material leading to a chronic source of water contamination. Chemical alterations will have a long-term effect on leaching characteristics. The major threat of water pollution from the mining of shale comes from the spent shale itself, rather than the oil that is drawn from it. A high potential exists for contamination of ground water by hazardous organic compounds leached from spent shale.

OBJECTIVE: (1) Describe the organic chemical composition and develop a data base of hazardous organic constituents associated with spent shale. (2) Evaluate the leaching properties from spent shale for selected hazardous organic compounds. (3) Develop chemical criteria for assessing the environmental impact of leaching upon ground water quality.

APPROACH: Samples of spent shale of various ages will be collected and subjected to chemical fractionation procedures. Each fraction will be analyzed by Capillary Gas Chromatography/Mass Spectrometry/Computer techniques. Definitive chemical characterization will be achieved through techniques such as **13C NMR and High Resolution Mass Spectrometry. A data base of organic pollutants associated with spent shale will be developed.

PROGRESS AND RESULTS: (A) Developed methodology for the isolation, characterization and determination of 19 selected volatile organic pollutants in water. (B) Presented a paper entitled "Determination of Selected Organic Priority Pollutants in Water by Computerized Gas Chromatography - Quadrupole Mass Spectrometry" at the 21st Rocky Mountain Conference on Analytical Chemistry, July 30, Denver, Colorado, 1979. (C) Co-authored a paper entitled "New Methods for Increasing Sensitivity and Selectivity in Gas Chromatography" at the 178th ACS National Meeting, Washington, DC, Sept. 10, 1979. (D) Published a paper entitled "Determination of Selected Volatile Organic Priority Pollutants in Water by Gas Chromatography - Quadrupole Mass Spectrometry" by H.E. Pereira and B.A. Hughes. (E) Developed Capillary GC-MS technology and new isolation techniques for the Characterization of Organic Pollutants in Bed Sediment from the Calcasieu River. and (F) Characterized various classes of organic pollutants in samples of volcanic ash obtained from Helena and Kalispell, Montana, and Richland

and Spokane, Washington.

COMPLETED REPORTS:

Picker, J.E., Yates, M.L., and Pereira, W.E., 1979, Isolation and Characterization of the chlorinated herbicide DCPA by GC-MS-computer techniques, Bulletin Environmental Contamination and Toxicology. 21, 612 (1979), 10 p.

Pereira, W.E., Short, D.L., Manigold, D.B., Roscio, P.K., 1979, Isolation and Characterization of TNT and its metabolites in ground water by GC-MS-computer techniques, Bulletin Environmental Contamination and Toxicology, 21, 554 (1979), 10 p.

Pereira, W.E., Hughes, B.A., 1980, Determination of Selected Volatile Organic Priority Pollutants in Water by Gas Chromatography-Quadrupole Mass Spectrometry, Jour. Amer. Water Works Assn. 72, 220, April 1980

CR218 Methods for Pesticides

PROJECT TITLE: The Evaluation and Development of Methods for Pesticides in Water and Sediments

WRD PROJECT NO.: CR 77-218

LOCATION: Topical Research

PROJECT CHIEF: Steinheimer, Thomas R.

HEADQUARTERS OFFICE: Arvada, CO

PROBLEM: Assessment of water quality relative to the presence of pesticide residues cannot be achieved without properly developed analytical techniques. Methods which can measure the changing environmental condition relative to pesticide use must be developed and tested for applicability to Water Resources Division (WRD) programs. Current use trends indicate the greatest needs to be in the areas of triazine and carbamate materials. These recently developed and widely used organic pesticides are being requested with increasing frequency and reflect the changing needs of District programs in water quality. Analytical capability for residue analysis needs to be expanded to meet this growing requirement.

OBJECTIVE: Apply principles of organic and microanalytical chemistry to the development of reliable procedures for measuring ug/L levels of triazine and carbamate materials. New methods will establish analytical protocols for processing samples for pesticide residues as well as other industrial organic chemicals. In addition, new techniques which expand the scope of trace organic analysis will be described in the chemical literature.

APPROACH: Apply wet chemical and instrumental techniques for pesticide analysis including extraction, "clean-up", and qual./quant. measurement. Investigate recent advances in pesticide isolation and recovery methods. Optimize separation parameters for chromatography. Evaluate new instrumental approaches, such as HPLC with specific detectors, (for potential application) to several classes of organic compounds. Pursue consensus among all elements of the scientific community by active promotion of WRD developed procedures.

PROGRESS AND RESULTS: (a) Continued development and refinement of a multi-residue HPLC method for the analysis of carbamate insecticides and herbicides. The method will include recovery of the difficult to analyze oxime carbamate materials which are being requested by the Districts. (b) Presented a paper entitled "Rapid Semi-quantitative analysis of selected pesticides in natural waters by high-pressure liquid chromatography", T.R. Steinheimer and S.M. Johnson, 21st Rocky Mountain Conference on Analytical Chemistry, Denver, Colorado, and at the 178th American Chemical Society Meeting, Washington, D.C., 1979. (c) Continued development of new techniques for direct removal of pesticide residues from water samples by trace enrichment. (d) Continued refinement and documentation of absorbance ratio for pesticide identification in water extracts. (e) Developed technique for isolation and characterization of organic pollutants residing on

bed sediment taken from the Calcaseiu River in Louisiana.

COMPLETED REPORTS:

Steinheimer, T.R., Johnson, S.M., 1979, Rapid semi-quantitative analysis of selected pesticides in natural waters by high-pressure liquid chromatography, 9 p.

CR219 Methods for trace metals

PROJECT TITLE: Development of instrumental methods for metal analysis

WRD PROJECT NO.: CR 77-219

LOCATION: Topical Research

PROJECT CHIEF: Taylor, Howard E.

HEADQUARTERS OFFICE: Arvada, CO

PROBLEM: The analysis of trace metals in water and water-related materials (i.e., suspended matter, bottom sediment, etc.) in a sensitive, accurate, and efficient manner, requires highly sophisticated analytical methodology. These methods employ instrumentation based upon physical and chemical properties. The solution of trace analysis problems (sensitivity, selectivity, interference effects, data collection/reduction and system automation) often require the design and construction of suitable instrumentation and apparatus. Even when existing equipment is available, an exhaustive optimization and evaluation from both an operational and statistical point of view is required before the method can be adopted. In addition, the study of specialized analytical problems, such as chemical speciation, requires unique approaches.

OBJECTIVE: (A) Investigate new concepts and approaches to instrumental methods of trace metal analysis. (B) Formulate methods and procedures for utilization of new instrumentation. (C) Evaluate the capability and performance of new instrumentation and methodology. (D) Develop automation technology of instrumentation to improve the efficiency and quality of data generation

APPROACH: (A) Maintain a periodic review of pertinent scientific literature and communicate frequently with colleagues and consultants who are involved in similar R and D programs. (B) Identify areas where improvement of existing instrumental methods can offer extended trace analysis capability and efficiency. (C) Design and perform experiments which will elucidate the significance of parametric variations in methods under development. Utilize statistical and factorial techniques to optimize and evaluate parametric factors. (D) Evaluate and optimize criteria such as accuracy, precision, interferences, sensitivity, selectivity, analysis efficiency and automation potential for each new or modified instrumental method or approach. (E) Perform extensive comparability studies between newly developed methods and existing or accepted procedures. (F) Prepare definitive reports and publications outlining the capability and function of newly developed methods and instrumentation.

PROGRESS AND RESULTS: (A) Technology has been developed for the determination of multiple elements in natural water systems by both inductively-coupled and direct current argon plasma spectrometry. Special data handling techniques and automated samplers have been devised for rapid processing of samples. A new nebulizer that is insensitive to suspended solids has been designed and evaluated. (B) A

simultaneous method for the ultratrace determination of Cu, Pb, Cd, and Zn by differential pulse anodic stripping volammetry has been developed. In addition, a method for the determination of thallium from ultralow to intermediate trace levels has been devised and evaluated on precipitation samples. (C) Research is proceeding on the development of X-ray fluorescence spectrometry for the direct determination of elemental composition of sediment material. (D) Studies have been carried out to physically and chemically characterize the composition of the Mt. St. Helens volcanic ash. Leaching experiments have been performed to evaluate the effect on the environment following rainfall events. (E) Development of technology for the reduction of interelement interference effects in graphite furnace atomic absorption spectrometry by the L'vov platform technique.

COMPLETED REPORTS:

Erdmann, D.E. and Taylor, H.E., 1978, An automated procedure for simultaneously determining specific conductance and pH in natural waters: Anal. Chim. Acta, 99, p. 269. (Also: Pittsburgh Conf. on Anal. Chemistry and Spectroscopy, No. 502).

Taylor, H.E. and Schroder, L.J., 1978, A lithium Isotope Ratio Technique for tracer or togging applications in natural water samples, Pittsburg Conf. on Anal. Chem. and Spectroscopy, No. 63, 1 p.

Garbarino, J.R. and Taylor, H.E., 1978, The application of an inductively-coupled plasma emission spectrometer for rapid quantitative analysis of natural waters: invited paper, Mid-Atlantic Regional American Chemical Society Meeting, Hunt Valley, Maryland, 1 p.

Bonelli, J.E., Taylor, H.E. and Skogerboe, R.K., 1978, Anodic stripping voltammetry for the simultaneous determination of ultratrace metals: Scope and Interference Effects: 20th Rocky Mountain Conference on Analytical Chemistry, Denver, CO., 1 p.

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WR065 CHEM. REACTIONS MIN. SURFACES

PROJECT TITLE: CHEMICAL REACTIONS AT MINERAL SURFACES

WRD PROJECT NO.: WR 70-065

LOCATION: Topical Research

PROJECT CHIEF: HEM, JOHN D.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: When solutes are introduced into a ground-water system, as in artificial recharge or waste injection, chemical reactions may occur between introduced and native materials. The reactions may precipitate solids that interfere with water movements, generate gases, or bring about various physical and chemical changes in the system surrounding the injection site. These changes may influence water movement and (or) composition. Mineral surfaces tend to catalyze some of the more important chemical reactions but their effect is poorly understood. Cation exchange and other sorption processes also influence concentrations of dissolved metal ions and the ways in which they are transported in river water.

OBJECTIVE: TO STUDY EFFECTS OF SPECIFIC MINERAL SURFACES ON RATES OF SUCH CHEMICAL REACTIONS AS HYDROXIDE OR CARBONATE PRECIPITATION, RELATING RATE TO NATURE AND AREA OF SURFACE EXPOSED, AND DETERMINING RATE CONSTANTS AND RELATED NUMBERS THAT CAN BE USED FOR DESIGN OR EVALUATION OF ACTUAL FIELD OPERATIONS. To evaluate specific adsorption processes of metal ions on stream sediments in dilute multi-ion solutions.

APPROACH: Experiments will be conducted in the laboratory using physical-chemical techniques to characterize surfaces and to measure reaction rates at various temperatures. Chemical equilibrium studies will be made in controlled laboratory solutions to evaluate exchange capacity and selectivity coefficients for common and minor elements on sediment and on selected mineral surfaces. Laboratory studies will be coordinated in part with studies of surface chemical systems to be conducted by contract research at Stanford University and with studies in project WR-57-076.

PROGRESS AND RESULTS: A computerized electrical double-layer (EDL) model developed earlier was applied to predict behavior of lead and sodium toward a silt-size natural stream sediment. The model gives useful results over a pH range of about 4.0 to 9.0. The presence of adsorbed polyacrylamide, a synthetic flocculating agent, on surfaces of kaolinite does not appear to influence significantly either the cation-exchange capacity or selectivity of the clay in a 0.01 molar Na**+ and CA**+ solution.

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WR076 CHEMISTRY OF HYDROSOLIC METALS

PROJECT TITLE: CHEMISTRY OF HYDROSOLIC METALS AND RELATED CONSTITUENTS OF NATURAL WATER

WRD PROJECT NO.: WR 57-076

LOCATION: NATIONWIDE

PROJECT CHIEF: HEM, JOHN D.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Hydrosolic metals are elements that form hydroxides with low solubility. The hydroxides may form colloidal suspensions (hydrosols). The elements generally cause problems in utilization of water and waste disposal either because of toxicity or because precipitates are formed in processes involving the water. Chemistry of these elements is complicated by effects of pH, redox potentials, inorganic or organic complexing, coprecipitation, and reaction rates.

OBJECTIVE: Define dilute-solution chemistry of elements of interest in the detail that is sufficient to apply findings to natural water systems; the final reports should be useful in predicting the fate of hydrosolic metals and associated substances, either in natural or polluted systems, as guides for designing optimal data collection programs and aids in the interpretation of water analyses and related hydrologic data.

APPROACH: Establish inorganic chemical model for behavior of element in dilute solution from literature and laboratory experiments. Test model in chemical laboratory studies, and with actual field data to determine applicability. Modify as necessary for kinetic and biochemical effects.

PROGRESS AND RESULTS: Operational rate constants for manganese oxide deposition from aerated aqueous solutions of Mn***2 have been determined. Where there are no catalytic effects except that of pre-existing oxide surface, the laboratory results extrapolate to a minimum growth rate for marine manganese nodules of 0.1 mm in about 800,000 years. This rate can be sustained by a water movement rate of about 3 mm day**-1. Water movement rates can be a critical factor in open systems where these oxides are deposited. Standard Gibbs free energy of feitknechtite (BMnOOH) was determined to be -129.8***+(-)0.6 kcal mole **-1. This is an unstable intermediate that can be altered to MnO(2) by disproportionation but it precipitates as the initial oxidation product in aerated laboratory solutions at temperatures near 0 degrees C. Hausmannite (MN(3)O(4)) predominates in these systems at 25 degrees C. Laboratory systems for converting MN**2+ by aeration at near-neutral pH to oxides in which the average Mn valence is 3.25+ or higher have been developed. The MN**4+ mission electron microscope ramsdellite or MnO(2). Techniques were developed for determining d-spacings by electron diffraction that are much more sensitive than standard x-ray diffraction for these synthetic preparations.

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WR080 GEOCHEMISTRY OF GEOTHERMAL SYSTEMS

PROJECT TITLE: GEOCHEMICAL STUDIES OF GEOTHERMAL SYSTEMS

WRD PROJECT NO.: WR 72-080

LOCATION: Topical Research

PROJECT CHIEF: BARNES, IVAN

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Geochemical data for geothermal systems are needed for estimating reservoir temperatures, outlining favorable exploration areas, identifying potential pollution problems, and estimating recharge-discharge relations as related to depletion. Corrosion and fouling problems also require such data. The CO(2) in the steam may be due to (1) metamorphic reactions or (2) mantle degassing. The chemical and isotopic character of volatiles issuing from volcanoes such as Mount St. Helens have not been adequately determined.

OBJECTIVE: Use chemical, mineralogic, and isotope data of gases, water and solids collected from geothermal areas to provide a detailed understanding of these systems in both their natural and disturbed states, and of volcanic systemsb efore, during, and after eruptions.

APPROACH: Field methods developed for the analyses of unstable constituents and special sample-collection and preservation techniques already in use will be applied to prospective geothermal areas and to areas around Mount St. Helens and possible other volcanoes. Data analysis by present and currently developing computer programs will be used.

PROGRESS AND RESULTS: Gas and water samples from the vicinity of Mount St. Helens were analyzed. Water is of meteoric origin. Gas anomalies are chiefly CO(2) and to a much lesser extent, SO(2). The findings will force a major reappraisal of volcanic mechanisms.

COMPLETED REPORTS:

Barnes, Ivan, Irwin, W.P., and White, D.E., 1978, Global distribution of carbon-dioxide discharges and major zones of seismicity: U.S. Geol. Survey Water Resources Inv. WRI-78-39, 12 p.

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WR124 GEOTHERMAL TRACE ELEMENT REACTIONS

PROJECT TITLE: TRACE ELEMENT REACTIONS AND DOWNSTREAM ATTENUATION PROCESSES IN WATERS OF GEOTHERMAL ORIGIN

WRD PROJECT NO.: WR 74-124

LOCATION: GEOTHERMAL AREAS

PROJECT CHIEF: Nordstrom, D. Kirk

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: The high trace-element content of geothermal waters is an important problem and may be a significant limitation on the development of geothermal power. Very little is known of precipitation and sorption processes which cause an attenuation of trace-element concentrations during storage in pools and during surface flow.

OBJECTIVE: Primary: To study and interpret the partitioning of trace elements among water, sediment, and selected biota, but especially among sediment components (iron oxides, organic matter, managnese oxides, carbonates, sulfides, etc.), and to identify the controlling processes. Secondary: Relate trace-element levels in geothermal waters to their geology, "type," temperature, and age of surface outlet, and to time as evidenced in shallow cores in winter.

APPROACH: Select one or more small stream systems draining a geyser area where the geology and hydrology are reasonably well known or is presently being studied. Sample water, suspended and bed sediments, and biota if present, perform appropriate analysis, and using both statistical and selective chemical extraction techniques, determine the partitioning among the various solid components and aqueous phase.

PROGRESS AND RESULTS: Plasma-spectrometry data collection and reduction have been virtually fully automated. Significant progress has been made in the quantitation of and automatic correction for interelement interferences due to six major elements, common in natural surface, ground and geothermal waters, Ca, Mg, K, Na, Si and Fe.

COMPLETED REPORTS:

Stauffer, R.E. and Thompson, J.M., 1978, Phosphorus in hydrothermal waters of Yellowstone National Park, Wyoming: U.S. Geol. Survey Jour. Res., v. 6, pp. 755-763.

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mineral equilibria of natural waters: U.S. Geol. Survey Water Res. Invest. 78-116, 138 p.

WR128 TRACE ELEMENT PARTITIONING

PROJECT TITLE: PROCESSES AND CONTROLS OF TRACE ELEMENT PARTITIONING IN NATURAL WATERS

WRD PROJECT NO.: WR 75-128

LOCATION: Topical Research

PROJECT CHIEF: JENNE, EVERETT A.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: (1) On carefully separated and preserved samples of dissolved and suspended sediments and of size-separated bed sediments, determine the content of trace elements and of each of the major sinks (organic matter, oxides of iron and manganese, carbonates, and sulfides). Evaluate the relative importance of the various sinks by statistical techniques (regression analysis, factor analysis). (2) Verify findings from (1) by experimental studies of selective dissolution and (or) extraction of the more important trace-element reservoir. Investigate sorption-desorption processes with radioactive isotopes.

OBJECTIVE: (1) Determine quantitatively the extent to which trace elements are complexed by dissolved organics in such a way that the organic ligands can be handled by the chemical model; (2) determine and interpret the processes, including precipitation, controlling the distribution of trace metals between natural waters and their associated suspended and bed sediments and indigenous biota; and (3) study the partitioning of trace metals among the various components of the bed sediment which serve as the principal trace-element sinks or reservoirs.

APPROACH: (1) On carefully separated and preserved samples of water and suspended sediments and of size-separated bed sediment, determine the content of trace elements and of each of the major sinks (organic matter, oxides of iron and manganese, carbonates, and sulfides). Evaluate the relative importance of the various sinks by statistical techniques (regression analysis, factor analysis). (2) verify findings from (1) by experimental studies of selective dissolution and(or) extraction of the more important trace-element reservoirs. Investigate sorption-desorption processes with radioactive isotopes.

PROGRESS AND RESULTS: Participated in Little Lost Man Creek inter-project interdisciplinary study of solute transport processes in unpolluted streams; studied trace-metal levels and determined stability constants for complexes of trace-metals with classes of naturally-occurring dissolved organic ligands. Completed analysis of samples collected from Little Lost Man Creek, as well as from San Francisco Bay and from Yellowstone Part hot springs, drainages and rivers. Expanded computer model WATEQ2, which calculates aqueous chemistry of major elements and of selected trace metals and ligands, to also include uranium calculations.

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WR139 Geochemistry of geopressured systems

PROJECT TITLE: Geochemistry of water in fine grained sediments

WRD PROJECT NO.: WR 76-139

LOCATION: California, Texas, Oklahoma, Louisiana

PROJECT CHIEF: Kharaka, Yousit K.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: The energy potential of geothermal waters from geopressured systems is enormous. Geochemical data are necessary for delineating favorable exploration areas, estimating the recoverable geothermthermal resources from a given reservoir, and identifying potential pollution, waste disposal, and corrosion problems.

OBJECTIVE: To study the chemistry and controls on the chemistry of water in geopressured geothermal systems. To provide basic data needed to identify potential pollution, waste-disposal, and corrosion problems associated with extraction of energy from these systems.

APPROACH: Collect water, gas, and rock samples from prospective geopressured systems for chemical, mineralogic, and isotopic analyses. Carry out membrane and water/rock-interaction studies in the laboratory. Data analyses will be performed by available and planned computer programs.

PROGRESS AND RESULTS: (1) Obtained 15 formation water samples from the Wilcox Formation of South Texas, 8 samples from 4 DOE geopressured geothermal wells and 12 samples from Houston-Galveston area of Texas. The salinity of waters is variable; salinity is lower in south Texas. The Formation waters are saturated with methane. (2) Carried out decarboxylation of acetate experiments with Bischoff (GD). Decarboxylation rates are fast and support our conclusion that acetate may be precursor to natural gas. (3) Worked with Berry (U of CA) on review of geopressured resources in California. California has potential for geopressure geothermal energy. (4) Modified SOLMNEQ to compute subsurface pH.

COMPLETED REPORTS:

Kharaka, Y.K., Carothers, W.W., and Brown, P.M., 1978, Origins of water and solutes in the geopressured zones of the northern Gulf of Mexico basin: Proc., 53rd annual meeting, Soc. Petroleum Engineers Preprint paper SPE 7505, 8 p.

Kharaka, Y.K., Brown, P.M., and Carothers, W.W., 1978, Chemistry of waters in the geopressured zone from coastal Louisiana--implications for the geothermal development: Transactions, Geothermal Resources Council, v. 2, pp. 371-374.

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Kharaka, Y.K., Callender, E., Chemerys, J.C. and Lico, M.S., 1979, Potential problems arising from the disposal of spent geopressured-geothermal waters from Coastal Texas & Louisiana: 1979, Proc. Marine Technol. Soc., p. II-47 - II-54

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Kharaka, Y.K., Carothers, W.W., Lico, M.S. and Wright, V.A., 1980, Chemical composition of geopressured geothermal waters from South Texas--implications for energy development: Abstract, ACS Meeting, Las

Vegas, NV, August, 1980

WR149 Organics in water

PROJECT TITLE: Chemistry of aquatic organic matter

WRD PROJECT NO.: WR 76-149

LOCATION: Topical research

PROJECT CHIEF: Goerlitz, Donald F.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Organic compounds, both naturally occurring and those resulting from man's activities may degrade water quality. The wide-spread findings of pesticides, plasticizers, and polynuclear aromatic hydrocarbons, in addition to the naturally occurring humic and fulvic acids are well documented. Recent advances in mathematical modeling of transport phenomena in ground water show promise of developing capability for predicting the intrusion of organic substances into ground water. Geochemistry of rock - water - organic waste interactions in the ground water flow systems is poorly understood. Equilibria and kinetics of the organics in the earth systems must be generally established before behavior and movement can be accurately forecast.

OBJECTIVE: Emphasis of this investigation will be on the physical-chemical interactions of relatively stable, water-soluble organic compounds of natural and man-made origin when introduced into a ground-water system. The project objectives will be: (1) To identify organic substances associated with a field problem related to introduction of selected pollutants into the environment; (2) To determine in the laboratory the equilibria and kinetics of reactions within the aqueous system as well as those that occur at the water - mineral interface; (3) To check the applicability of the above relationships to the field behavior of the organics in question. Organic substances influencing inorganic phenomena (chelation, etc., of heavy metals) and the biochemical aspects of such systems are considered beyond the scope of this work.

APPROACH: This is a multidisciplinary project involving advanced mathematical modeling, field hydrology, and geochemistry, as well as aquatic chemistry. Hence it will involve cooperative work with another project entitled "Mathematical modeling of organic solute transport in ground water," J B Robertson, project chief. In the subject project, a survey of the state of present knowledge regarding adsorption, degradation rates, etc., for selected compounds will be made. Specific organic chemical compounds and representative polar-nonpolar, acid, base, and neutral compound classes will be selected for study, based on their known or anticipated presence within the study site, and with due consideration of their physiological significance or other relevance to pollution problems. Study sites will be selected on the basis of availability of hydrologic and geologic data, suitability for modeling requirements, and accessibility for field investigation, in cooperation with J B Robertson. Chromatographic methods and other appropriate procedures will be used for chemical analyses. Kinetic and equilibrium studies using batch and column techniques will be performed,

performed, using aquifer and earth materials from the study site as necessary. Hypotheses developed in the laboratory studies will be applied in the field for testing.

PROGRESS AND RESULTS: Project has been terminated.

COMPLETED REPORTS:

Goerlitz, D.F., 1979, Analysis of picric acid in water by high-performance liquid chromatography: U.S. Geol. Survey Open-file Report, 7 p.

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WR165 Western U.S.--Geothermal Waters

PROJECT TITLE: Chemical and Isotope Studies of Thermal Waters of the Western U.S.

WRD PROJECT NO.: WR 79-165

LOCATION: Western United States

PROJECT CHIEF: Mariner, Robert H.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Reconnaissance and chemical and isotope sampling of thermal springs in the western United States has not generally provided information of sufficient detail to permit the geothermal potential of most individual areas to be determined with any certainty. This is especially true in the Cascades, where the chemical geothermometers indicate much lower temperatures of water-rock equilibrium than the sulfate-isotope geothermometer and the geologic setting seem to require. This discrepancy could be due to simple mixing of thermal and fresh water or rapid equilibration of water with the surrounding country rock as the fluids rise to the surface; alternatively, the sulfate-isotopic composition could be an artifact reflecting the original source.

OBJECTIVE: The origin of the dissolved constituents, water, and gases discharging in the hot springs will be investigated and their relationship to the fumaroles and cold mineral springs ascertained. Recharge areas for the thermal springs will be determined as well as the amount of mixing of thermal and nonthermal waters. With this information, individual systems can be better understood and the geothermal potential of the individual thermal reservoirs estimated with greater accuracy.

APPROACH: Samples of water and gas discharging from thermal, cold, and mineral springs will be subjected to chemical and isotopic analysis. The chemical and isotopic data will then be used to determine the extent of mixing and ascertain the probable recharge areas for the individual thermal systems. The factors which control the chemical and isotopic composition of the fluids will also be investigated. Although the initial area of investigation will be the Cascades of California, Oregon, and Washington, other geothermal areas in the western United States will be investigated as the project develops.

PROGRESS AND RESULTS: Thermal spring areas sampled in the Oregon Cascades are well confined with relatively little leakage. Isotope samples were collected for determination of recharge sources. Oxygen isotopic analyses of dissolved sulfate and water from thermal springs in the Great Basin indicate that the sulfate-water isotope geothermometer preserves evidence of high temperatures (more than 180 degrees C) better than the quartz geothermometer. Several springs which discharge isotopically-depleted sulfate, normally an indication of high temperature, obtain the sulfate from mineral sources. Also, use of a computer model to estimate aquifer-pH based on the pH and

chemical composition of water discharged at the surface markedly improves agreement between the quartz or chalcedony and Na-K-Ca geothermometers in alkaline water.

COMPLETED REPORTS:

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Nehring, N.L., Mariner, R.H., White, L.D., Huebner, M.A., Roverts, E.D., Harmon, Karen, Bowen, P.A., and Tanner, Lane, 1979, Sulfate geothermometry of thermal waters in the western United States: U.S. Geol. Survey Open-file Report, 11 p.

Mariner, R.H., Swanson, J.R., Orris, G.J., Presser, T.S. and Evans, W.C., 1980, Chemical and isotopic data for water from thermal springs and wells of Oregon: Open-File Report 80-737, 50 p.

CR189 Geochemical Kinetics Studies

PROJECT TITLE: Geochemical kinetics studies

WRD PROJECT NO.: CR 75-189

LOCATION: Topical Research

PROJECT CHIEF: Claassen, Hans C.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Adequate description of mass transport in hydrologic systems requires the knowledge of the kinetics of solid-liquid phase interactions. The rates and products of chemical reactions changes in (relative) surface area with time, and the relationship of surface/volume ratio to bulk solution composition are needed for adequate water-quality systems modeling. Careful study of the environmental parameters controlling the rate and products of the interaction of recharging water with the lithologic environment are necessary to aid in the design of laboratory experiments to quantify these parameters.

OBJECTIVE: Model systems representing single lithologies (1) extrusive volcanic; (2) shale are studied to determine the relative importance of the parameters controlling water quality and experiments are devised to quantify the process. These experiments are designed to deduce the kinetics and mechanism(s) of these processes and the effects of natural variation in the controlling parameters. Models are devised to predict natural water quality and the results compared with that found in nature.

APPROACH: Reaction sequences using both individual mineral phases and whole rock (volcanic tuffs and natural shales) will be carried out in aqueous medium under controlled solution composition (viz P CO2 and oxidation potential) by a method developed by Claassen and White. Time-sequence analyses will be made of both solid and liquid phases to determine changes in surface area, mineralogical composition and major elements in solution. These reaction sequences will be performed for systems of various surface/volume ratio and mineralogical composition.

Individual components of the solid phase will also be reacted separately to assess any synergism among the components of the multi-component synthetic and natural materials studied. Predictions of the effects of surface-area and solution-composition changes on minor-element transport, based on the results of the above studies, will be compared with equilibrium sorption data obtained by traditional methods.

PROGRESS AND RESULTS: A digital kinetic model describing the diffusion-controlled dissolution of a rhyolitic glass was developed. This model takes into account variations in surface-to-volume ratio, pH, and temperature. The effect of solute concentration variations on reaction rate is described by use of Freundlich sorption isotherm. Initial reaction consists of a rapid ion exchange on the solid surface and establishment of a metastable equilibrium. Mass transfer is subsequently controlled by the various hydrogen ion-cation codiffusion

rates. Diffusion of zerovalent species is pH-independent; however, charged species have diffusion rates which are dependent on hydrogen ion contentration, bivalent ions being more dependent than monovalent ions. This results in a solution composition which is determined by the pH of reaction and explains the composition of ground waters associated with tuffs in parts of southern Nevada. The obtainment of a sorption isotherm for natural material from kinetic data will allow meaningful comparisons to be made between different materials and will allow prediction of sorption behavior of species not subjected to laboratory scrutiny. The correspondence between laboratory-predicted and field-measured sorption will be tested in a volcanic-rock system having a well characterized surface. In order to eliminate some of the drawbacks associated with lysimeters, a tool for obtaining samples of so-called "free" water passing through the soil zone was developed. Application of laboratory kinetic data to estimate the effective surface area in a partially-saturated groundwater system was also completed. This is the first time that a technique to determine this parameter, important for realistic modeling of waste transport, has been presented.

COMPLETED REPORTS:

Claassen, H.C. and White, A.F., 1979, Application of Geochemical Kinetic Data to Groundwater, Part I: A Tuffaccous-Rock Aquifer in Southern Nevada: ACS Symposium on Chemical Modeling - Speciation, Sorption, Solubility and Kinetics in Aqueous Systems, 1978, 34 p.

White, A.F. and Claassen, H.C., 1979, Dissolution Kinetics of Silicate Rocks-Application to solute Modeling: ACS Symposium on Chemical Modeling - Speciation, Sorption, Solubility and Kinetics in Aqueous Systems, October 22, 1978, 26 p.

White, A.F., and Claassen, H.C., 1980, Kinetic model for the short-term dissolution of a rhyolitic glass: Chemical Geology, v. 28, p. 91-109

White, A.F., Claassen, H.C., and Benson, L.V., 1980, The effect of dissolution of volcanic glass on the water chemistry in a tuffaceous aquifer, Rainier Mesa, Nevada: U.S. Geol. Survey Water-Supply Paper 1535-Q (in press)

White, A.F., and Claassen, H.C., 1980, A case for diffusion kinetics as a control on the weathering of glassy volcanic rocks at 25 degrees C. Extended abstract for Water/Rock Interaction Symposium, Edmonton, Alberta, Canada, July 1980 (in press)

CR205 NTS Geochemistry

PROJECT TITLE: Geochemistry of Ground Water at Nuclear Test Areas

WRD PROJECT NO.: CR 77-205

LOCATION: Southern Nevada

PROJECT CHIEF: Claassen, Hans C.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Estimate the flow rates and residence times in an aquifer as ground water moves from areas of recharge to areas of discharge. Such information would be of value both to ERDA for evaluating environmental impact of activities related to test activities and to the scientific community in general.

OBJECTIVE: Define the geochemical history of major isotope and chemical species in order to use established methods such as carbonate isotope dating and developing techniques such as kinetic modeling to better define flow paths and residence times.

APPROACH: Several ground-water systems at NTS are excellent areas in which to compare residence times predicted by kinetic reaction rates and **14C age dating methods. Changes in solute chemistry, particularly of carbonate species, must be evaluated in detail to account for isotope dilution. Study of the recharge areas will furnish information on the initial phase of the geochemical reaction path and progressive chemical reactions can be traced downgradient.

PROGRESS AND RESULTS: A geochemical kinetic model based on laboratory data was derived which successfully simulates ground-water compositions at residence times and pHs comparable to natural ground waters associated with rhyolitic rocks in southern Nevada. Such a model allows for determination of effective surface areas in contact with percolating ground water. Analysis of the results obtained for the Rainier Mesa ground-water system indicates that although measurements of water saturation is high (77 to 90 percent), the major water-transmitting region of the aquifer is only about 3 percent of the total porosity. Such an approach should result in more realistic waste-transport modeling.

COMPLETED REPORTS:

White, A.F. and Claassen, H.C., 1979, Disolution Kinetics of Silicate rocks-application to solute modeling" in Chemical Models in Aqueous Systems, Ed. E.A. Jenne: ACS Symposium Series 93, Chapter 22, 26 p.

Claassen, H.C. and White, A.F., 1979, "Application of geochemical data to ground water systems. A tuff-aceous-rock system in southern Nevada," in Chemical Models in Aqueous Systems, Ed. E.A. Jenne: ACS Symposium eries 93, Chapter 34, 34 p.

White, A.F., 1979, Geochemistry of ground water associated with tuffaceous rocks, Oasis Valley, Nevada: U.S. Geological Survey

Professional Paper 712E, 38 p.

CR223 Transuranium Research

PROJECT TITLE: Transuranium Research

WRD PROJECT NO.: CR 77-223

LOCATION: Topical Research

PROJECT CHIEF: Cleveland, Jesse M.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Contamination of natural waters by transuranium elements will be a growing concern because of the increasing amount of radioactive waste disposal. Plutonium, although considered to be highly insoluble, has been detected in some waters at higher than predicted concentrations. Other elements, such as americium and neptunium are more soluble and hence more mobile than plutonium. It is important that the chemical and physical forms of these elements in natural waters, their reaction with other constituents (such as organic solutes) in the water system, and their hydrologic behavior be elucidated if valid criteria for the safe long-term disposal of radioactive wastes are to be established.

OBJECTIVE: The objectives of the project are: (1) to characterize the chemical and physical forms of plutonium, americium, and neptunium in contaminated natural waters; (2) to establish the interactions of these elements with other solutes in natural waters; (3) to determine the hydrologic behavior of these elements; (4) to interpret and present this information in a manner useful for the establishment of satisfactory waste disposal criteria.

APPROACH: The approach will include the following procedures: (1) determination of the degree of polymerization of plutonium, americium, and neptunium in natural waters by filtration through membrane filters of submicron pore size; (2) establishment of the electrical charge of these elements as present in natural waters by anion and cation exchange and possibly electrophoresis; (3) determination of the chemical associations of these elements with organic solutes by means of column separations followed by radiometric analysis of the various organic species; (4) elucidation of the role of carbonate and bicarbonate in these systems; (5) after adequate characterization, to study the interactions of these elements with representative soils and minerals.

PROGRESS AND RESULTS: Completed sampling, analysis and plutonium characterization of trench leachates from the Maxey Flats (WY) radioactive waste disposal site. Results indicated that plutonium is largely noncolloidal (i.e., in true solution), in the reduced form (tri- and tetravalent), and is complexed by organic species including EDTA. Paper describing these findings has been submitted to Science magazine. Have sampled four wells at Idaho National Engineering Laboratory (INEL) and one well at Nevada Test Site (NTS). Results from NTS well will be available near end of FY80.

CR251 Water quality and health

PROJECT TITLE: Relationship between chemical quality of natural waters and human health and disease

WRD PROJECT NO.: CR 79-251

LOCATION: Topical Research

PROJECT CHIEF: Feder, Gerald L.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: In recent years there has been increasing interest and study concerned with the possible relationships between the chemical quality of natural waters and human health and disease. Medical researchers recognize areal patterns of health and disease in the U.S. and suspect that these patterns may be controlled by both environmental and non-environmental factors. After excluding non-environmental factors it appears that local and regional differences in water quality may have an effect on health and disease. Such differences influence the total dietary intake of necessary major and trace elements and the concentration of certain potentially toxic chemical constituents.

OBJECTIVE: The objective of the proposed study is to determine if there are relationships between the chemical quality of natural waters and human health and disease.

APPROACH: The first step in this study will be to identify chemical constituents occuring in natural waters which are most likely to affect health and disease and to identify those medical conditions most likely to be affected by water quality. This information will be used to determine the temporal and spacial associations between specific chemical characteristics of water and specific states of health and disease. In this study, known high risk factors related to geographic areas (e.g., urban environment, mining activity) will be excluded in order to increase the likelihood of detecting risk factors associated with natural water quality. Initially both the medical and hydrologic aspects of the study will rely on existing data from data storage centers such as the U.S. Geological Survey and the Bureau of Vital Statistics. However, if data are lacking, field collection of new data is planned. Project data collection will be supplemented by cooperative programs with district and great aquifer study water quality specialists. Information on chemical composition of soils, rocks, and plants will be obtained through informal cooperation with the Branch of Regional Geochemistry, GD.

PROGRESS AND RESULTS: Completed field water-quality sampling of South Atlantic Coastal Plain and Ogallala aquifer. Conferred with Dr. H.C. Hopps on trace elements in water that may affect human health. Atlantic Coastal Plain ground waters have very low concentrations of most chemical constituents. The lack of chemical constituents may be of importance to human health.

COMPLETED REPORTS:

Federa, G.L., 1979, Geochemical survey of waters of Missouri: U.S. Geol. Survey Professional Paper 954-E, 78 p.

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Whittemore, D.O., Savage, M.H., Feder, G.L., 1980, Geochemistry of bromide and iodide in natural waters: Implications for tracer studies (abs): EOS, Transactions American Geophysical Union, v. 61, no. 17, p. 233

McKnight, D.M., Feder, G.L., Thurman, E.M., Wershaw, R.L., 1980, Interactions among copper, humic substances and hydrous metal oxides in streams (abs): Abstracts of Papers submitted for the Fourty-Third Annual Meeting, American Society of Limnology and Oceanography, Inc., June, 1980, p. 10

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CR258 Uranium mill tailings

PROJECT TITLE: Hydrochemical controls on the migration of radionuclides from uranium mill tailings

WRD PROJECT NO.: CR 78-258

LOCATION: Topical Research

PROJECT CHIEF: Landa, Edward R.

HEADQUARTERS OFFICE: Denver, CO

PROBLEM: Radium appears to be the most important non-gaseous radioactive contaminant associated with uranium mill tailings. Therefore, research will be aimed at assessing its state in the tailings, and its potential mobilization and retention in natural aqueous systems.

OBJECTIVE: (1) Characterize the physical, chemical and mineralogic nature of uranium mill tailings, with particular reference to radium distribution. (2) Determine the mobility of radium associated with uranium mill tailings and surficial earth materials. (3) Examine the hydrogeochemical controls on ground and surface-water transport of radium.

APPROACH: (1) Sampling of uranium mill tailings at active and inactive sites. (2) Sampling of high radium brines and associated sediments in coastal marsh. (3) Determination of factors effecting sorption of radium from brines by sediments. (4) Determine effect of sulfate-reducing bacteria on radium mobilization from tailings. (5) Determination of chemical mineral associations of radium in tailings and sediments by selective extraction techniques.

PROGRESS AND RESULTS: (1) Publication of Circular 814. (2) Outfitting of research lab in Denver. (3) Near completion of study of Ra-sorption by marsh sediments; awaiting final analysis - anticipated by November 1980. (4) Begin comparative study of associations of Ra-226, Th-230, and uranium in uranium ore and its derived mill tailings; anticipate completion in mid FY 81. (5) August 1980 - begin work on sulfate reducing bacteria.

COMPLETED REPORTS:

Landa, E.R., 1980, Isolation of uranium mill tailings and their component radionuclides from the biosphere - some earth science perspectives: U.S. Geological Survey Circular 814, 32 p.

NR018 MINERALOGIC CONTROL GROUND WATER

PROJECT TITLE: MINERALOGIC CONTROLS OF THE CHEMISTRY OF GROUND WATER: I. ENVIRONMENTAL ISOTOPE RESEARCH; II. MEMBRANE PROPERTIES OF CLAYS

WRD PROJECT NO.: NR 67-018

LOCATION: Topical Research

PROJECT CHIEF: HANSHAW, BRUCE B.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: I. ACCURATE DATING OF GROUND WATER PROVIDES DATA ON RATE AND DIRECTION OF MOVEMENT AND PROVIDES AN INDEPENDENT MEANS OF DETERMINING PERMEABILITY AND POROSITY DISTRIBUTIONS. THIS INFORMATION CAN BE USED DIRECTLY IN THE SOLUTION OF PROBLEMS CONCERNING ARTIFICIAL RECHARGE AND SUBSURFACE WASTE DISPOSAL. II. NATURAL SHALE MEMBRANES MAY AFFECT WATER CHEMISTRY BY ULTRAFILTRATION AND CHANGE FLUID PRESSURE BY OSMOSIS. UNDERSTANDING OF THESE PROCESSES MAY PROVIDE IMPORTANT INSIGHT INTO ORIGIN AND CONTROL OF ANOMALOUS FLUID PRESSURES; THEORY RELATES DIRECTLY TO TOPICS SUCH AS (1) EARTHQUAKE ACTIVITY, (2) DESALINIZATION, (3) ARTIFICIAL RECHARGE, (4) SUBSURFACE WASTE, (5) GEOTHERMAL POWER, (6) DRILLING OPERATIONS, ETC.

OBJECTIVE: I. TO EVALUATE AND PERFECT THE RADIOCARBON DATING TECHNIQUES APPLIED TO GROUND WATER. TO USE LIGHT STABLE ISOTOPES TO CHARACTERIZE SPECIFIC FORMATION WATERS AND TO DETERMINE SPECIFIC MINERAL-WATER INTERACTIONS. II. TO UNDERSTAND THE ROLE THAT SHALE MEMBRANES PLAY IN THE CONTROL OF SUBSURFACE PRESSURE AND WATER CHEMISTRY.

APPROACH: THE ISOTOPIC COMPOSITION OF FIELD SAMPLES OF WATER AND COEXISTING MINERALS ARE BEING DETERMINED TO STUDY THE FRACTIONATION OF HYDROGEN, OXYGEN, CARBON AND SULFUR IN NATURE. A CLAY COMPACTION PRESS CAPABLE OF MEASURING A VARIETY OF ELECTROKINETIC PHENOMENA IS BEING USED TO STUDY THE MEMBRANE PROPERTIES OF COMPACTED CLAYS.

PROGRESS AND RESULTS: Several manuscripts have been finished for publication including an opus magnus on the Madison aquifer system. Computer modeling of mixing fresh and saline ground water indicate that under appropriate conditions, one can dissolve calcite and dolomitize it within the same milieu.

COMPLETED REPORTS:

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Hanshaw, B.B. and Hallet, Bernard, 1978, Oxygen isotope composition of subglacially precipitated calcite: Possible paleoclimatic implications: Science, v. 200, n. 4347, pp. 1267-1270.

Hanshaw, B.B., Busby, John, and Lee, Roger, 1978, "Geochemical aspects of the Madison aquifer system": in Williston Basin Symposium

published by the Montana Geological Society, pp. 385-389.

Hanshaw, B.B., Pearson, F.J., Jr., and Winograd, I.J., 1978, Deuterium and oxygen-18 content of Holocene through Late Wisconsin precipitation: Geol. Soc. Amer., Abstract with Programs, v. 10, n. 7, pp. 415-416.

Back, William, Hanshaw, B.B., Pyle, T.E., Plummer, L.N., and Weidie, A.E., 1979, Geochemical Significance of Groundwater Discharge to the Formation of Caleta Xel Ha, Quintana Roo, Mexico: Water Resources Research, v. 15, no. 6, pp. 1521-1535.

Hanshaw, B.B., and Back, William, 1979, Major Geochemical Processes in the development of carbonate aquifer systems: Jour. Hydrology, v. 43, pp. 287-312.

Hanshaw, Bruce B., and Back, W., 1980, Chemical Mass-wasting of the Northern Yucatan Peninsula by ground-water solution, Geology, v. 8, p. 222-224

NR020 MINERAL-WATER INTERACTION IN SALINE ENVIRONMENT

PROJECT TITLE: MINERAL-WATER INTERACTION IN SALINE ENVIRONMENTS

WRD PROJECT NO.: NR 69-020

LOCATION: topical research

PROJECT CHIEF: JONES, BLAIR F.

HEADQUARTERS OFFICE: RESTON, VA

PROBLEM: SALINE HYDROLOGIC SYSTEMS PROVIDE A WIDE RANGE OF CONDITIONS WITHIN WHICH TO EXAMINE HYDROCHEMICALLY IMPORTANT MINERAL REACTION, ALTERATION OR GENESIS, AND TO BETTER DEFINE REACTANTS AND PRODUCTS CONTROLLING THE CHEMICAL COMPOSITION OF MANY NATURAL WATERS. THE EFFECTS OF COMPLEX REACTIONS IN ADDITION TO SIMPLE SOLUTION AND HYDROLYSIS ARE REFLECTED IN RELATIVELY GROSS CHEMICAL CHANGE AND INTERACTION WITH FINE-GRAINED SEDIMENT.

OBJECTIVE: TO UTILIZE SALINE ENVIRONMENTS TO DETERMINE MECHANISMS AND RELATIVE IMPORTANCE OF MINERALOGIC PROCESSES WHICH INFLUENCE THE SOLUTE COMPOSITION OF NATURAL WATERS.

APPROACH: FIELD STUDY AND LABORATORY ANALYSIS IS MADE OF SALINE WATERS AND ASSOCIATED DEPOSITS, MOSTLY FROM SURFICIAL SITES OR SHALLOW CORES IN SELECTED PILOT OR PROBLEM AREAS. SOLID AND SOLUTION PHASE SEPARATION AND EXAMINATION INVOLVES HIGH SPEED AND GRADIENT CENTRIFUGATION, MICROSCOPY, X-RAY DIFFRACTOMETRY, AND SPECIAL POTENTIOMETRIC APPARATUS, AS WELL AS DETAILED CONSTITUENT ANALYSIS OF BOTH SOLIDS AND SOLUTIONS. COMPOSITION OF THESE MATERIALS IS THEN RELATED TO THE HYDROCHEMICAL ENVIRONMENT, THERMODYNAMIC CONDITIONS AND STRUCTURAL ELEMENTS OF ASSOCIATED MINERAL SPECIES.

PROGRESS AND RESULTS: Further refinement of data from Lake Abert, OR and the Amargosa Desert, NV, on transformations resulting from variable interaction of volcanoclastic materials with ground and surface waters is revealing a sequence in clay mineral character dependent on relative rates of solute transport and concentration. Lack of "chain clays" or diagnostic mixed layer phases in mineralogic analysis of alluvial materials from Frenchman Flat (Nevada Test Site) has led to more extensive study of secondary cements and volcanic glass alteration to identify former water table conditions. Two volcanic ash markers, and distinctive stratigraphic intervals representing variable lake conditions, have been delineated in piston cores from Great Salt Lake. A major shift in carbonate mineralogy reflecting changes in lake chemistry, plus evaporite zones and their effects on pore fluid profiles, have also been recognized. Replicate analyses of very concentrated brines from the Rustler-Salado evaporites of SE New Mexico have been coupled with normative calculation of equilibrium salt assemblages to suggest solution origins. Distinctive clay mineral suites have been recognized in the upper and lower Potomac River estuary. The fresher water assemblage contains more kaolin plus vermiculite and less expandable clay species.

COMPLETED REPORTS:

Jones, B.F., and Bowser, C.J., 1978, The mineralogy and related chemistry of lake sediments: Chapt. 7 in "Lakes: Chemistry, Geology, Physics," A. Lerman, ed., Springer-Verlag, N.Y., 55 p.

Eugster, H.P., and Jones, B.F., 1979, Behavior of major solutes during closed-basin brine evolution: Amer. Jour. Sci., v. 279, p. 609-631, 22 p.

Deike, R.G., and Jones, B.F., 1980, Provenance, distribution, and alteration of sediments in a saline alkaline lake: in "Hypersaline Brines and Evaporitic Environments", A. Nissenbaum, ed., Chapter 14, 25 p.

NR034 CHEMICAL CONSTITUENTS OF WATER

PROJECT TITLE: SPATIAL DISTRIBUTION OF CHEMICAL CONSTITUENTS IN GROUND WATER

WRD PROJECT NO.: NR 57-034

LOCATION: Topical Research

PROJECT CHIEF: BACK, WILLIAM

HEADQUARTERS OFFICE: RESTON, VA

PROBLEM: THERE IS A NEED TO BE ABLE TO PREDICT THE CHEMICAL AND PHYSICAL CHANGES THAT OCCUR WITHIN AN AQUIFER OWING TO STRESSES IMPOSED UPON THE HYDROLOGIC SYSTEM. THESE STRESSES MAY BE THE RESULT OF NATURAL OR ARTIFICIAL RECHARGE OF GOOD QUALITY WATER FROM INJECTION OF WASTE WATER OR FROM WITHDRAWALS OF WATER SUPPLIES.

OBJECTIVE: TO UNDERSTAND THE CHEMICAL REACTIONS BETWEEN WATER AND EARTH MATERIALS; THESE REACTIONS ARE THE PROCESSES BY WHICH THE WATER ATTAINS THE OBSERVED CHEMICAL CHARACTER.

APPROACH: TO DESCRIBE THE FIELD RELATIONSHIPS BETWEEN THE CHEMISTRY OF THE WATER AND THE GEOLOGIC AND HYDROLOGIC ENVIRONMENT, AND TO IDENTIFY PROBLEMS THAT ARE AMENABLE TO SOLUTION BY APPLICATION OF CHEMICAL THERMODYNAMICS; TO IDENTIFY AND MEASURE THE VARIABLES THAT CONTROL THE ENVIRONMENT; AND TO INTERPRET THE MEASUREMENTS WITHIN THE THEORETICAL FRAMEWORK PROVIDED BY REVERSIBLE AND IRREVERSIBLE THERMODYNAMICS.

PROGRESS AND RESULTS: Work has continued to study organic reactions and their effect on inorganic reactions; to determine reactions in lake sediments; and to determine role of ground water in geomorphic processes.

COMPLETED REPORTS:

Baedecker, Mary Jo, and Back, William, 1979, Hydrogeological processes and chemical reactions at a landfill: Ground Water, v. 17, no. 5, p. 429-437, 8 p.

Back, William, Baedecker, Mary Jo, and Wood, Warren W., 1979, Hydrochemical processes in coastal plain aquifers, in Program and Abstracts, Second Symposium on the Geology of the Southeastern Coastal Plain, Univ. of Southwestern Georgia, p. 6, 1 p.

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Baedecker, Mary Jo, and Back, William, 1979, Modern marine sediments as a natural analog to the chemically stressed environment of a landfill: Jour. Hydrology, v. 43, no. 1-4, p. 393-414, 11 p.

Back, William, and Stephenson, D.A., 1979, Contemporary Hydrogeology--The George Burke Maxey Memorial Volume: Elsevier, 569 p.

Baedecker, Mary Jo, 1979, Generation of Gases and fractionation of Stable Isotopes in landfills: EOS (Am. Geophys, Union Trans.), v. 60, p. 258, 1 p.

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Hanshaw, B.B., and Back, William, 1979, Major geochemical processes in the development of carbonate aquifer systems: Jour. Hydrology, v. 43, p. 287-312, 25 p.

Plummer, L.N., and Back, W., 1980, The mass balance approach; application to interpreting the chemical evolution of hydrologic systems, Amer. Jour. of Science, v. 280, p. 130-142, 13 p.

Baedecker, M.J., 1980, Hydrogeochemistry near landfills in selected geologic terranes, International Geo. Cong. Abstract, v. 111, sec. 15, p. 1081, Paris, 1 p.

Wood, W.W., 1980, Hydrodynamic dispersion and cation exchange capacity in regional ground-water systems, Inter. Geologic Cong., Abstract, v. 111, sec. 15, p. 1167, Paris, 1 p.

Back, W., 1980, Geochemistry of groundwater in North America--in historical perspective and prognosis, International Geologic Congress, Abstract, v. 1, 111, sec. 15, p. 1080, 1 p.

Hanshaw, Bruce B., and Back, W., 1980, Chemical Mass-wasting of the Northern Yucatan Peninsula by ground-water solution, Geology, v. 8, p. 222-224, 3 p.

NR041 Interface hydrochemistry & paleoclimatology

PROJECT TITLE: Interface of geochemistry, paleoclimatology, and hydrogeology in study of regional aquifer systems

WRD PROJECT NO.: NR 74-041

LOCATION: Topical research

PROJECT CHIEF: WINOGRAD, ISAAC J.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: Studies of regional aquifer systems commonly emphasize either hydraulic, hydrogeologic, hydrochemical, or isotopic facets of ground water. Interdisciplinary syntheses appear mandatory for development of types of data unobtainable through additional, though detailed, study of any single one of the cited disciplines. Examples of new knowledge anticipated from such syntheses include: influence of hydrodynamics on water chemistry; identification of major heterogeneities in transmissivity from geochemical data; climatic changes during residence time of water in an aquifer; and quantitative assessments of seasonal recharge to major uplands.

OBJECTIVE: (1) Appraise practical worth of the environmental isotopes (deuterium, tritium, C-13, C-14, D-18, and S-34) and hydrochemistry as tools for studyo f recharge to, flow in, and mixing properties of, unstressed, stressed, or polluted aquifer systems. (2) Evaluate effects of mixing (including crossflow) and dual sources of porosity on water geochemistry; (3) Reconstruct paleoclimate of selected regions from variations in isotopic content of ground water and of calcitic veins and tufas deposited by these waters. (4) Date ground water at proposed and existing radioactive waste disposal sites. (5) Differentiate between, and determine relative magnitude of, summer versus winter recharge to major uplands receiving near equal quantities of summer and winter precipitation.

APPROACH: (1) Sample selected regional aquifers for which quantitative hydrogeologic studies have been completed. Compare and contrast interpretations of flow system made on basis of hydrodynamic, hydrochemical, and isotopic data. (2) Sample rain, snow, snow melt, springs and shallow ground waters in major upland recharge areas. (3) Sample calcitic veins and tufa deposits. Compare and contrast temporal fluctuations in isotopic (0-18) content of the radiometrically dated carbonate deposits with that in aquifer waters. Attempt reconstruction of paleoclimate. Dating will utilize, C-14, thorium-230/uranium and uranium 234/238 methods.

PROGRESS AND RESULTS: (1) Completed a major report (for Prof. Paper series) on the paleohydrology of the Southern Great Basin. Principal conclusion of this work is that even during pluvial climates of the late Pleistocene, the southern Great Basin was marked by deep water tables and long ground-water flow paths. The fluctuations in water table that occurred were small in comparison to the present depth to water and would not preclude use of the Nevada Test Site as a repository for radioactive waste; and completed a report (to be

published in Science) suggesting that solidified transuranic radioactive wastes can be safely isolated from the hydrosphere for tens to hundreds of millenia by their placement at shallow depths (30-100 m) in thick unsaturated zones of those portions of the Great Basin undergoing crustal extension. Moreover, such disposal could be accomplished with a savings of about 500 million dollars in comparison with current plans to place these wastes in deep (600-900 m) mines.

COMPLETED REPORTS:

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Donath, F.A., Greenwood, T.R.I., Klingsberg, C., McGrath, P.E., Nichols, J., Stewart, D.B., and Winograd, I.J., 1978, Isolation of radioactive wastes in geologic repositories: Status of scientific and technological knowledge: Office Science and Technology Policy, Executive Branch, 89 p.

Donath, F.A., Greenwood, T., Klingsberg, C., McGrath, P.E., Nichols, J., Stewart, D.B., and Winograd, I.J., 1979, Technical issues in nuclear waste isolation, in, The State of Waste Disposal Technology and the Social and Political Implications, R.G. Post, editor: Univ. of Arizona, Tucson, p. 45-60,. 15 p.

Winograd, I.J., and Doty, G.C., 1980, Paleohydrology of the southern Great Basin, with special reference to water table fluctuations beneath the Nevada Test Site during the late (?) Pleistocene, Open-file # 80-569 (in press), 95 p.

Winograd, I.J., 1980, Radioactive waste disposal in thick unsaturated zones of the Great Basin--An example from Yucca Flat, Nevada, Science (in press), 46 p.

NR056 Modeling mineral-water reactions

PROJECT TITLE: Kinetic and thermodynamic modeling of mineral-water reactions in natural water systems

WRD PROJECT NO.: NR 76-056

LOCATION: Topical

PROJECT CHIEF: Plummer, Leonard N.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: In order to model the chemical quality of ground water systems, it is necessary to determine what reactions are occurring and their rates. Virtually nothing is known of the rates of mineral-water interaction in ground water systems. Furthermore, little is known of the effects of variable composition on the stability of minerals, as well as the stability of metastable and amorphous phases which apparently regulate, to a large extent, the composition of certain low-temperature natural waters.

OBJECTIVE: To obtain experimental data on the kinetics of mineral dissolution-precipitation reactions, investigate the effects of variable composition of minerals and the stability of metastable and amorphous phases in regulating the composition of natural waters, and relate these data to modeling the chemical evolution of natural waters.

APPROACH: Laboratory dissolution and precipitation reactions involving carbonate minerals are monitored by potentiometric measurement and analysis of bulk fluids at controlled PCO(-2) and temperature as a function of time. Computer calculations solve the surface kinetics which are fundamental in nature and can be applied to predicting rates of reactions in natural environments. Mineral stability is obtained from reversed solubility measurements and in some cases the rate of approach to equilibrium, both as a function of temperature. Kinetic and thermodynamic data coupled with hydrodynamic mass transport equations model the chemical evolution of ground water systems.

PROGRESS AND RESULTS: The dissolution kinetics of aragonite was studied between 0 and 70 degrees C. The controlling mechanisms are similar to those of calcite with rate constants for surface controlled processes approximately twice those found for calcite. The solubility of calcite, aragonite and vaterite was measured between 0 and 90 degrees C at two CO(2) partial pressures. New measurements for the dissolution kinetics of calcite using a weight loss method support the proposed reaction mechanism. Hydrodynamic effects on the rate of dissolution of calcite and aragonite were investigated using rotating disks.

COMPLETED REPORTS:

Plummer, L.N., Wigley, T.M.L., and Parkhurst, D.L., 1978, The Kinestics of Calcite Dissolution in CO(2)-water systems at 5 degrees

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Wigley, T.M.L., Plummer, L.N., and Pearson, F.J., 1978, Mass Transfer and Carbon Isotope Evolution in Natural Water Systems: Geochim. Cosmoc im. Acta, v. 42, pp. 1117-1139.

Pearson, F.J., Jr., Fisher, D.W., and Plummer, L.N., 1978, Correction of Ground-Water Chemistry and Carbon Isotopic Composition for Effects of CO(2) Outgassing. Geochim. Cosmochim. Acta. v. 42, p. 1799-1807

Thorstenson, D.C., and Plummer, L.N., 1978, Equilibrium Criteria for Two-Component Solids Reacting wih fixed Composition in an Aqueous Phase - Example: The Magnesian Calcites: Reply to Discussions. Amer. Jour. Sci. v. 298, p. 1478-1488

Nordstrom, D.K., Plummer, L.N., and others, 1979, A Comparison of Computerized Aqueous Models. In: Jenne, E.A., Editor, Chemical Modeling in Aqueous Systems, Amer. Chem. Soc. Symp. Ser. 93, p. 857-892

Plummer, L.N., Wigley, T.M.L., and Parkhurst, D.L., 1979, A Critical Review of the Kinetics of Calcite Dissolution and Precipitation. In Jenne, E.A., Editor, Chemical Modeling in Aqueous Systems, Amer. Chem. Soc. Symp. Ser. 93, p. 537-573

Sundquist, E., Plummer, L.N., and Wigley, T.M.L., 1979, Carbon Dioxide in the Ocean Surface: The homogeneous buffer factor, Science, v. 204, p. 1203-1205

Back, William, Hanshaw, B.B., Pyle, T.E., Plummer, L.N., and Weidie, A.E., 1979, Geochemical Significance of Groundwater Discharge and Carbonate Solution to the Formation of Caleta Xel Ha, Quintana Roo, Mexico. Water Resources Res., v. 15, pp. 1521-1535, 15 p.

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NR064 ISOTOPE FRACTIONATION

PROJECT TITLE: PHYSICAL CHEMISTRY OF STABLE ISOTOPE FRACTIONATION IN HYDROLOGIC PROCESSES

WRD PROJECT NO.: NR 75-064

LOCATION: Topical

PROJECT CHIEF: COPLEN, TYLER B.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: SEVERAL LIGHT STABLE ISOTOPES (H, C, N, O, SI, AND S) SHOW VARIATIONS IN THEIR ISOTOPE ABUNDANCES AND OFFER GREAT PROMISE FOR STUDY OF EVAPORATION, GROUND-WATER MIXING, LAKE OR RESERVOIR CIRCULATION AND STRATIFICATION AND ASSOCIATED HYDROCHEMICAL PHENOMENA. THESE ISOTOPE FRACTIONATIONS ARE RELATED TO: (1) PURELY PHYSICAL PROCESSES; (2) HETEROGENEOUS CHEMICAL EQUILIBRIA; AND (3) REACTION KINETICS. MANY OF THESE PROCESSES ARE NOT SUFFICIENTLY UNDERSTOOD OR QUANTIFIED TO MAKE THE MOST EFFECTIVE USE OF STABLE ISOTOPE TECHNIQUES IN HYDROLOGIC RESEARCH.

OBJECTIVE: REFINED THEORETICAL AND INSTRUMENTAL MASS SPECTROMETRIC TECHNIQUES WILL BE DEVELOPED THROUGH EXPERIMENTAL INVESTIGATION, AND TESTED IN SUITABLE FIELD LOCATIONS, SUCH AS INTERMONTANE GROUND-WATER RESERVOIRS, CLOSED-LAKE BASINS, AND SUITABLE SURFACE RESERVOIR, LAKE, OR ESTUARINE SYSTEMS, TO AID IN MORE COMPLETE UTILIZATION OF LIGHT STABLE-ISOTOPE PHENOMENA IN HYDROLOGIC STUDIES.

APPROACH: WATER AND MINERAL SAMPLES FROM EXPERIMENTAL STUDIES, FROM EVAPORATING SURFACE WATER BODIES, AND FROM GROUND-WATER BASINS, WILL BE ANALYZED FOR LIGHT STABLE ISOTOPE ABUNDANCES. THESE EXPERIMENTAL RESULTS AND FIELD DATA WILL THEN BE RELATED TO OTHER MEASUREMENT FACTORS SUCH AS RELATIVE HUMIDITY, TEMPERATURE, DENSITY, AND SALINITY, IN AN ATTEMPT TO DEVELOP AN UNDERSTANDING AND A THEORETICAL PREDICTIVE MODEL OF THE PROCESSES INVOLVED.

PROGRESS AND RESULTS: We have nearly completed several hundred oxygen and hydrogen isotope analyses of Cerro Prieto geothermal fluids and of surrounding cold waters. Preliminary interpretations indicate that the ground water is derived from the Colorado River whereas the salt is partially derived from an oceanic source. A mass spectrometer has been set up by Carol Kendall for nitrogen - 15 stable isotope analysis. Sample preparation lines have nearly been completed. The primary use of this equipment will be to investigate the uses of stable nitrogen isotopes in ground water, surface water, and sediment studies. A theoretical study of the strontium carbonate technique used by WRD to collect and prepare dissolvedc arbon-13 samples of ground and surface water has been completed by Afifa Hassan. This study indicated that probably less than two percent of carbon is lost inm ost samples. An experimental study was begun to confirm theory and to develop an improved sampling and preparation procedure.

COMPLETED REPORTS:

Pearson, F.J. and Coplen, T.B., 1978, "Stable isotope studies of Lakes" in Lakes: Chemistry, Physics, Geology, A. Lerman, Ed., 18 p.

Truesdell, A.H., Nehring, N.L., Thompson, J.M., Coplen, T.B., Desmarais, D.J., Janik, C.J., and Mehl, D.C., 1980, Geochemical studies of the Cerro Prieto reservoir fluid, second symposium on the Cerro Prieto geothermal field, Baja California, Mexico, 3 p.

NR065 Transition Metal Hydrogeochemistry

PROJECT TITLE: Transition Metal Geochemistry of Natural Waters

WRD PROJECT NO.: NR 76-065

LOCATION: Topical

PROJECT CHIEF: Callender, Edward

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: Transition metals are among the more important chemical components of aquatic systems; many transition metals are considered environmentally hazardous at higher than trace levels, and their solid precipitates act as a host carrier for other potentially toxic metals of environmental concern. Understanding geochemical processes that control the transition metal chemistry of natural waters is requisite for predicting the effects man-induced events will have upon the metals' natural geochemical cycles and for determining their utilization as a natural resource (e.g. geothermal brines as mineral resources; estuarine waters as food resources).

OBJECTIVE: (1) To quantitatively describe the important geochemical processes affecting transition metal and nutrient chemistry of several different natural water types; (2) To assess the influence man's activities exert on their natural geochemical cycles; and (3) To evaluate transition metal hydrogeochemistry in terms of water resource utilization.

APPROACH: Sample and analyze surface water, ground water, and sediment/rock pore water for transition metal and nutrient content of aqueous phase and associated solid phase(s). The primary analytical method used in this study will be flame and flameless atomic absorption spectrophotometry and ion chromatography. Analytical data will be evaluated in terms of important water/rock-sediment system variables (temperature, pressure, redox, dissolved organics). Results will be modeled in terms of solution mineral equilibria, sorption/ion exchange, and advective/diffusive transport through porous sedimentary media.

PROGRESS AND RESULTS: Interstitial water data collected on five cruises from 1978 to 1980 have been evaluated in terms of diffusive nutrient fluxes from sediment into overlying water. In the lower Potomac Estuary, the diffusional fluxes of ammonia, phosphate, and silica are generally high reflecting the degradation of sedimented organic matter. In the transition zone, fluxes of ammonia are significantly lower and fluxes of phosphate are somewhat lower than in the lower estuary. Ammonia pore water gradients are much less steep due to benthic mixing while the phosphate gradients do not appear to be affected by the same process. For tidal river sediments, fluxes of ammonia are as high as those for the lower estuary, but the fluxes of phosphate are extremely low. These low phosphate fluxes suggest that sedimented phosphorus is retained within the sediment. The project has been investigating another method for estimating long-term benthic fluxes using the chemical data on sediment solids from cores.

COMPLETED REPORTS:

Callender, E., 1978, Geochemistry of Potomac River estuarine sediments and associated interstitial water: EOS, v. 59, no. 12.

Hearn, P.P. and Callender, E., 1978, Geochemistry of suspended particulate matter in the tidal Potomac River: EOS, v. 59, no. 12.

Kharaka, Y.K., Callender, E. and Carothers, W.W., 1979, Geochemistry of Geopressured Geothermal Waters from the Texas Gulf Coast: Proceed., Third Geopress. Geotherm. Energy Conf., Lafayette, La., p. GI1121-165, 46 p.

Hearn, P., Callender, E., and Ruppert, L., 1979, Factors Determining the Distribution of Dissolved and Particulate phosphorous in the Potomac River Estuary: EOS; v. 60, 1 p.

Callender, E., and Bowser, C.J., 1980, Manganese and copper geochemistry of interstitial fluids from manganese nodule-rich pelagic sediments of the northeastern equatorial Pacific Ocean: Am. Jour. Science In press, 40 p.

NR085 GASES, COMPLEXES IN WATER

PROJECT TITLE: GASES AND SOLUTE COMPLEXES IN WATER

WRD PROJECT NO.: NR 73-085

LOCATION: topical research

PROJECT CHIEF: FISHER, DONALD W.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: PROGRESS IN STUDIES OF THE GEOCHEMISTRY OF WATER DEPENDS IN PART ON MORE DETAILED KNOWLEDGE OF WATER COMPOSITIONS. THE EXTENT OF COMPLEX FORMATION AND THE CONCENTRATIONS OF DISSOLVED GASES ARE AMONG THE PROPERTIES WHICH MUST ALSO BE DETERMINED. STUDIES FOR WHICH SUCH ADDITIONAL INFORMATION IS NECESSARY INCLUDE THE GEOCHEMISTRY OF GROUND WATERS IN CARBONATE AND SULFIDE ROCKS, THE REACTIONS OCCURRING AT LAKE BOTTOMS, AND IN FLOODED MINES, AND SUBSURFACE WASTE DISPOSAL STUDIES.

OBJECTIVE: THE OBJECTIVES OF THE PROJECT ARE TO DEVELOP TECHNIQUES FOR DETERMINING KINDS AND CONCENTRATIONS OF DISSOLVED GASES AND SOLUTE COMPLEXES IN NATURAL WATERS, AND TO APPLY THE RESULTING METHODS TO THE SOLUTION OF PARTICULAR GEOCHEMICAL PROBLEMS.

APPROACH: THE ANALYTICAL CAPABILITY FOR THE CHROMATOGRAPHIC ANALYSIS OF DISSOLVED GASES WILL BE REFINED AND ENLARGED TO INCLUDE ALL OF THE NATURALLY OCCURRING GASES. IMPROVED GAS SAMPLING DEVICES, CAPABLE OF COLLECTING WATER SAMPLES UNCONTAMINATED BY THE ATMOSPHERE, WILL BE DEVELOPED AND TESTED. THE SOLUTE COMPLEX PHASE OF THE PROJECT WILL BE CONCERNED WITH REFINING OUR ESTIMATES OF COMPLEXING IN REAL SYSTEMS FOR WHICH PUBLISHED STABILITY CONSTANT DATA ARE INADEQUATE TO ACCOUNT FOR OBSERVED WATER COMPOSITIONS. TECHNIQUES TO BE USED WILL INCLUDE ULTRAVIOLET AND VISIBLE SPECTROPHOTOMETRY, POTENTIOMETRIC AND SPECIFIC-ION ELECTRODE METHODS AND EVENTUALLY INFRA-RED SPECTROPHOTOMETRY AND OTHER METHODS.

PROGRESS AND RESULTS: Perched waters and waters collected in lysimeters near the Gascoyne, N.D. lignite mine contain very high concentrations of dissolved sulfate. In 8 of 10 such samples, Thorstenson and Fisher (Reston) and Croft (Bismark) find levels of sulfate greater than the equilibrium concentration attainable by simple dissolution of gypsum. In general, the higher sulfate concentrations (up to 16,000 mg/l) are in water from shallower depths, although the trend is not uniform. Sodium and sodium magnesium sulfate salts from surface crusts probably provide some of the sulfate found in these shallow waters above water table in the Tongue River aquifer unit. Below the water table in this aquifer, sulfate levels appear to depend on the presence or absence of lignite. Beyond the present outcrop of the lignite, mean sulfate concentration of samples from 14 wells is 2,609 mg/l; where the lignite seam overlies the sandstone aquifer unit, average sulfate concentration of samples from 14 wells is 530 mg/l.

COMPLETED REPORTS:

Pearson, F.J., Jr., Fisher, D.W., and Plummer, L.N., 1978, Correction of Ground-Water Chemistry and Carbon Isotopic Composition for Effects of CO(2) Outgassing: Geochim. et Cosmochim. Acta, v. 42, 1799-1807, 9 p.

Hobba, W.A., Jr., Fisher, D.W., Pearson, F.J., Jr., and Chemerys, J.C., 1979, Hydrology and geochemistry of thermal springs of Appalachians. U.S. Geol. Survey Prof. paper 1044-E, p. E1-E36, 36 p.

Thorstenson, D.C., Fisher, D.W., and Croft, M.G., 1979, The geochemistry of the Fox Hills-basal Hell Creek aquifer in southwestern North Dakota and northwestern South Dakota: Water Resources Research, v. 15, no. 6, p. 1479-1498, 20 p.

NR093 Redox reactions

PROJECT TITLE: Redox reactions in ground waters

WRD PROJECT NO.: NR 79-093

LOCATION: Topical

PROJECT CHIEF: Thorstenson, Donald C.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: Redox potential remains the least understood major control on natural water chemistry. The goal of this research is better characterization of the factors that determine redox potential in ground-water systems. An understanding of the major processes governing redox reactions must be available in order to attempt modeling of the ground-water geochemistry of compounds of multivalent elements such as iron, manganese, or uranium and other actinides.

OBJECTIVE: (1) Identify controls on redox potential in specific natural systems; (2) Evaluate processes responsible for the distribution of oxygen and carbon dioxide in the unsaturated zone; (3) Apply computer models to redox reactions in natural hydrologic systems; and (4) Improve techniques for measuring redox potential.

APPROACH: (1) Integration of fundamental thermodynamics of redox processes and natural water geochemistry; (2) Measurements of gas composition and isotopic characteristics of carbon dioxide in the deep unsaturated zone; (3) Application of computer models to specific redox problems in ground-water systems; and (4) Assemble an electrochemical laboratory for examination of time-response characteristics of redox measurements.

PROGRESS AND RESULTS: (1) First phase of study of aqueous electrons and thermodynamics completed; manuscript in preparation; (2) Isotopic analysis of unsaturated zone CO(2) to depths of 100 feet now available for sites in North Dakota and Texas; and (3) Data from Gascoyne, N.D., indicates that depth of the lignite below land surface is the dominant factor controlling ground-water geochemistry.

COMPLETED REPORTS:

Thorstenson, D.C., Fisher, D.W., and Croft, M.G., 1979, Geochemistry of the Fox Hills-Basal Hell Creek Aquifer in Southwester North Dakota and Northwestern South Dakota, Water Resources Research, 25 p.

Thorstenson, D.C. and Plummer, L.N., 1978, Equilibria Criteria for Two-Component Solids Reacting with Fixed Composition in an Aqueous Phase-Example: the Magnesian Calcites. A reply to discussions: Am. J. Sci., 278, 1478-1488, 10 p.

NR099 Geologic perspectives - global CO(2)

PROJECT TITLE: Geological evidence for global carbon fluxes and their climatic effects

WRD PROJECT NO.: NR 79-099

LOCATION: Topical Research

PROJECT CHIEF: Sundquist, Eric T.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: Rising atmospheric carbon dioxide (CO(2)) concentrations and man's increasing consumption of fossil fuels have led to concern for the future effects of atmospheric CO(2) on global climate. Much geologic evidence indicates that the natural global CO(2) system may have fluctuated significantly before man's influence, and that these natural changes may have been associated with global climate changes. Studies of the natural variations are necessary in order to anticipate any comparable effects in the future.

OBJECTIVE: To investigate by numerous methods available, through Survey scientists, the possibility of past variations in the world's (natural) CO(2) balance. To determine interrelationships between any such variations and global climate. To apply geologic information to the prediction of future global CO(2) fluxes and their climatic implications. To provide technical framework for coordination of USGS research related to the global CO(2) problem.

APPROACH: A variety of geochemical techniques, including stable isotope and carbon-14 measurements, will be applied to geological samples from appropriate time periods. These data will be interpreted within the context of a computer model of the global CO(2) system.

PROGRESS AND RESULTS: (1) Quantitative evaluation of the homogeneous CO(2) buffer factor in the ocean surface. (2) Implementation of global CO(2) computer model. (3) Draft proposal for Department of Energy support of coordinated U.S. Geol. Survey CO(2) research program.

COMPLETED REPORTS:

Sundquist, E.T., Plummer, L.N., and Wigley, T.M.L., 1979, Carbon Dioxide in the Ocean Surface: the homogeneous buffer factor: Science, v. 204, p. 1203-1205

Sundquist, E.T., and Miller, G.A., Oil shales and carbon dioxide: Science, v. 208, p. 740-741, 2 p.

NR102 Hydrologic studies of paleoclimate

PROJECT TITLE: Isotopic studies of hydrologic systems related to paleoclimate

WRD PROJECT NO.: NR 79-102

LOCATION: Topical Research

PROJECT CHIEF: Hanshaw, Bruce B.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: Little is known about the isotopic composition of the Pleistocene ice sheets and about variations in the isotopic composion of ancient precipitation. Determination of these data may allow for a correction of the foraminifer isotopic paleothermometer by allowing calculations of shifts in the ocean's isotopic composition.

OBJECTIVE: To understand shifts in climatic patterns and to estimate temperature changes in the ancient oceans which attended glacial maxima and minima.

APPROACH: Stable isotope studies of subglacially precipitated carbonates of modern and Pleistocene age. Isotopic investigations of regional aquifer systems to determine mean annual temperature changes of recharge. Studies of datable bog material and their isotopic variations.

PROGRESS AND RESULTS: Major carbonate quarries in New York with exposed surfaces were examined for Pleistocene-age sub-glacial precipitates; four excellent sample sites were discovered and sampled.

CR085 WATER QUALITY MODELING

PROJECT TITLE: GROUND-WATER QUALITY MODELING

WRD PROJECT NO.: CR 73-085

LOCATION: Topical Research

PROJECT CHIEF: Grove, David B.

HEADQUARTERS OFFICE: Denver, CO

PROBLEM: The accidental or planned injection of contaminants into the ground-water environment will cause changes in the water quality that may have serious implications as to the future use of this ground-water resource. Prediction of these changes are necessary to allow a decision making capability prior to injection as well as to provide remedial action in case of accidental contamination.

OBJECTIVE: To demonstrate the applicability of numerical modeling techniques to the prediction of water quality changes during transport of solutes through the saturated ground-water systems and to analyze the effects of these changes on the ground-water environment.

APPROACH: Solve the mass-transport equation through numerical means using finite difference and finite element methods and thus produce a water-quality model that will predict the effects of chemical disturbances on the ground-water system. Evaluate the effects of the disturbances on the aquifer. Involve a system orientated approach concentrating on the use of field data and laboratory experiments to verify the model. Work closely with District, Federal and State research projects involved in similar studies.

PROGRESS AND RESULTS: Approximately 20 solute transport and associated programs have been installed on the Multics and CDC computers. A one-dimensional solute transport model with various types of linear and nonlinear reaction terms has been completed and is in the process of being documented. The numerical stability of the radial transport equation used in the Survey waste injection program (SWIP) was critically analyzed and a letter report prepared for District users. Modification of this program to make it more efficient and to correct some errors has been a continual process. Field studies have continued at Telluride, Colorado, where hexavalent chromium has contaminated the alluvial valley. Laboratory analysis have indicated that the chromium concentration is decreasing and moving slowly down the valley. Consultation with District personnel from Louisville, KY concerning organic solute movement has resulted in a more complete understanding of the fractionation of organic solutes during the movement through porous media.

COMPLETED REPORTS:

Grove, D.B., 1977, The use of Galerkin finite element methods to solve mass transport equations: U.S. Geol. Survey Water Resources Investigations 77-49, 55 p.

Grove, D.B., 1976, Ion exchange reactions important in ground-water quality models: Advances in Groundwater Hydrology, American Water Resources Association, September, pp. 144-152.

Grove, D.B., and Wood, W.W., 1979, Prediction and field verification of subsurface-water quality changes during artificial recharge, Lubbock, Texas: Groundwater, v. 17, no. 3, p. 250-257, 8 p.

Grove, D.B., Miller, R.L., Konikow, L.F., and O'Boyle, P.S., 1979, Hexavalent chromium in ground and surface waters near Telluride, Colorado - a preliminary data report: U.S. Geol. Survey Open-File Report 79-700, 18 p.

INTERA Environmental Consultants, Inc., 1979, Revision of the documentation for a model for calculating effects of liquid waste disposal in deep saline aquifers: U.S. Geol. Survey Water Resources Investigations 79-96, 73 p.

Miller Ronald, 1978, Input-output models for nutrients with the application for models to Lake Okeechobee, Florida: U.S. Geol. Survey Journal Research, v. 6, no. 6, p. 821-828.

Kipp, Kenneth L., 1980, Mathematical modeling of chemical transport in soil columns: EOS v. 61, no. 17, p. 234

NR037 TURBULENT DIFFUSION AND THERMAL LOADING

PROJECT TITLE: HYDRODYNAMIC STUDY ON THE TRANSPORT (CONVECTIVE DIFFUSION) OF THERMAL, PHYSICAL, AND CHEMICAL CONSTITUENTS IN TURBULENT SURFACE WATER

WRD PROJECT NO.: NR 68-037

LOCATION: Topical Research

PROJECT CHIEF: YOTSUKURA, NOBUHIRO

HEADQUARTERS OFFICE: RESTON, VA

PROBLEM: UNDERSTANDING AND MODELING OF TURBULENT TRANSPORT (CONVECTIVE DIFFUSION) IS THE FOUNDATION FOR QUANTITATIVE DESCRIPTION AND PREDICTION OF DISTRIBUTION OF THERMAL, PHYSICAL, AND CHEMICAL CONSTITUENTS IN STREAMS, LAKES, AND ESTUARIES. NEED FOR THE CONSTITUENT MODEL IS RAPIDLY INCREASING BECAUSE OF NATIONALLY FELT PRESSURE FOR OPTIMUM ALLOCATION OF SURFACE WATER RESOURCES AS WELL AS FOR CONTROLLING WATER POLLUTION. SPECIALLY URGENT IS THE DEVELOPMENT OF THERMAL MODELS BECAUSE OF POTENTIAL POLLUTION EXPECTED FROM A LARGE-SCALE NUCLEAR POWER GENERATION.

OBJECTIVE: TO DEVELOP MATHEMATICAL MODELS FOR THE TRANSPORT OF THERMAL AND OTHER CONSTITUENTS IN SURFACE WATER. INCORPORATE INTO THE TRANSPORT MODEL SOME ADDITIONAL COMPONENTS SUCH AS HEAT DISSIPATION THROUGH BOUNDARIES, CHEMICAL AND BIOLOGICAL REACTIONS, SINK AND SOURCE TERMS SO THAT THE END PRODUCTS ARE REASONABLY COMPREHENSIVE AND OPERATIONAL AS CONSTITUENT MODELS. THE DETERMINATION OF DIFFUSION COEFFICIENTS FROM DATA BY USE OF THE ABOVE MODELS IS ANOTHER OBJECTIVE OF THE PRESENT STUDY.

APPROACH: DETERMINISTIC APPROACH BASED ON THE HYDRODYNAMIC EQUATIONS OF MOTION AND MASS CONTINUITY, THE TRANSPORT EQUATION BEING DERIVED FROM THE CONTINUITY OF CONSTITUENT MASS IN A SEGMENTED WATER BODY. THE EQUATIONS ARE SOLVED ANALYTICALLY AND/OR NUMERICALLY. THE SUPERPOSITION PRINCIPLE IN A LINEAR SYSTEM IS UTILIZED IN ARRIVING AT SOLUTIONS WHENEVER IT IS PRACTICABLE AS AN APPROXIMATION. ALSO THE STOCHASTIC RELATIONSHIPS BETWEEN INPUT AND OUTPUT WILL BE INVESTIGATED IN A SET OF LINEARIZED DIFFERENTIAL EQUATIONS.

PROGRESS AND RESULTS: Completed rewriting earlier draft on analysis of existing mixing data as the comprehensive report on the steady-state transport of solutes in nonuniform natural rivers. The report illustrates various prototype applications of the nondimensional stream-tube model by use of one-dimensional parameters. Completed also the draft on an estimation of reaeration coefficient in the Cuyahoga River, Ohio, by the spectral analysis of time series data obtained in 1976 and 1977. The reaeration coefficient varied between 2.7 and 7.7 day **-1.

COMPLETED REPORTS:

Yotsukura, N., 1979, Stream-Tube Model for Two-Dimensional Transport in a Steady Nonuniform Channel Flow: Abstract, Spring Annual Meeting,

American Geophysical Union, Washington, D.C., 1 p.

Holley, E.R., and Yotsukura, N., 1979, Thermal Boundary Conditions for Water Flow with Moving Boundaries: U.S. Geol. Survey Open-File Rept. 79-743, 30 p.

Jennings, M.E., and Yotsukura, N., 1979, Status of Surface-Water Modeling in the U.S. Geol. Survey, U.S. Geol. Survey Circ. 809, 17 p.

NR048 Hydrologic Interpretations

PROJECT TITLE: Hydrologic Interpretations based on Heat-Flux Analyses and the application of Remotely Sensed Information

WRD PROJECT NO.: NR 70-048

LOCATION: EASTERN UNITED STATES

PROJECT CHIEF: PLUHOWSKI, EDWARD J.

HEADQUARTERS OFFICE: RESTON, VA

PROBLEM: Aside from thermal loading stemming from powerplant operations, little has been done to assess man's influence on the thermal patterns of natural streams. Near stream environmental changes due to man's activities may adversely impact stream ecology by altering stream temperatures. In addition to stream-temperature problems, evaluation of remote sensing instrumentation as a method of detecting sources of thermal pollution, sedimentation, and erosion in large water bodies as well as current circulation has obvious application to a wide variety of hydrologic problems.

OBJECTIVE: (A) to isolate and evaluate the effect of man-imposed changes on stream-temperature patterns; (B) identify stream-temperature patterns under a variety of climatic regimen; (C) to assess near shore current patterns in Lake Ontario using turbidity plumes as tracers; (D) to evaluate the utility of the Landsat III thermal imager as a means of detecting thermal plumes in the Lake; and (E) to continue work in defining the utility of remotely sensed land-use information as a means of improving streamflow estimates.

APPROACH: Pairs of watercourses consisting of a "control" stream (one under essentially natural conditions) and one or more streams that have been altered by man's activities have been instrumented in selected basins of the northeast U.S. Comparisons on "altered" stream and its control should reveal the effects of environmental changes on water-temperature patterns. High-altitude photographs and Landsat imagery will be used to detect transitory hydrologic phenomena such as heat and turbidity plumes, shoreline erosion, and ground-water inflow to streams.

PROGRESS AND RESULTS: Stream temperature predictions in a small stream based on a comprehensive mass transport-heat flux model produced generally excellent results. Despite the low thermal inertia of the stream (North Fork Muddy Creek near South River, MD) standard deviations of predicted minus observed values of daily maximum and minimum water temperatures at the outlet of the 1.4 km study reach were 0.4 degrees C and 0.2 degrees C, respectively. Test runs include five runs each consisting of six consecutive days beginning November 1970 and ending June 1971. Although daily maximum and minimum temperature predictions were close to observed, the half-hourly temperature values generated by the model tended to be high during the forenoon and early afternoon and low during the late afternoon and evening hours during April and June. This may be due to streambed absorption of solar energy during the morning and a release of this

energy to the stream during the late afternoon and at night.

COMPLETED REPORTS:

Pluhowski, E.J. and Spinello, G.A., 1978, Impact of sewerage systems on stream base flow and ground-water recharge on Long Island, New York: U.S. Geol. Survey Jour. Research, v. 6, No. 2, 9 p.

SR033 Thermal Modeling

PROJECT TITLE: Thermal modeling of water systems

WRD PROJECT NO.: SR 73-033

LOCATION: Topical Research

PROJECT CHIEF: JOBSON, HARVEY E.

HEADQUARTERS OFFICE: NSTL Station, MS

PROBLEM: Need to obtain a better understanding of transport and surface exchange processes such that water temperatures can be more accurately predicted.

OBJECTIVE: To improve the current methods of predicting the transport and surface exchange of thermal energy in water systems.

APPROACH: Models will be developed and verified for temperature prediction in the following categories: (1) reservoir where vertical temperature stratification is an important factor, (2) reservoirs which are well mixed vertically, and (3) river systems. In developing these models, studies will be conducted on energy transfer processes at the air water interface as well as mixing processes occuring in reservoir inflows and outflows.

PROGRESS AND RESULTS: A practical Lagrangian model for the transport of 10 interactive constituents has been developed and documented. This model represents a significant improvement over existing Eulerian type transport models both in accuracy and ease of operation. A 363-day record of evapotranspiration from replacement vegetation in the Gila River valey of Arizona has been created from energy budget measurements. When combined with evapotranspiration measurements from different hydrologic areas, this record will be used to develop an evapotranspiration model from a heterogeneous basin.

COMPLETED REPORTS:

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Jobson, H.E., 1978, Thermal modeling of flow in the San Diego Aqueduct, CA, and its relation to evaporation: U.S. Geol. Survey Open-File Report 78-1026, NSTL Station, MS, 62 p.

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SR055 Organic substances in streams

PROJECT TITLE: Transport and degradation of organic substances in streams.

WRD PROJECT NO.: SR 77-055

LOCATION: Topical research

PROJECT CHIEF: Rathbun, Ronald E.

HEADQUARTERS OFFICE: Bay St. Louis, MS

PROBLEM: Organic substances discharged into streams affect water quality and possible uses of the water. To quantify the effect of organics on water quality, the chemical, physical, and biological processes involved in the transport, degradation and determination of the ultimate fate of these substances must be understood.

OBJECTIVE: Determine the fundamentals of the microbial degradation and the fundamentals of the volatilization, dispersion, adsorption, and other physical processes that affect the concentrations of organic substances in streams. Develop sub-models of these processes and integrate these sub-models into an overall model describing the transport and degradation of organic substances in streams.

APPROACH: Perform controlled laboratory studies (stirred tank and/or flume) to determine the degradation characteristics of specific organic compounds, both as single components and as mixtures and controlled studies of the transport and degradation of these substances in the small model river at NSTL. Apply the results of these studies to the testing, adapting or developing of transport models for organics in streams; Test these models under field conditions.

PROGRESS AND RESULTS: A continuous 32-day injection of acetone on the NSTL model river was completed. Rhodamine-WT dye was injected for 36 hours and for 24 hours at the beginning and near the end, respectively, of the experiment to define the hydraulics and dispersion. Tertiary butyl alcohol was injected for 12 hours on the 4th day to determine the vaporization characteristics of the river. Acetone concentrations were monitored at three points in the river, and preliminary analysis of the data suggests that the acetone was not being degraded by the bacteria or that the acetone was degraded at a much slower rate than expected based on laboratory degradation rates. Growth chambers for monitoring bacterial growth without interference from algal growth functioned well; however, oxygen diffusion through the end membranes apparently became limiting after about five days. Preliminary analysis of ATP data from water and sediment samples suggested no increase and perhaps some decrease of biomass during the experiment. Diel oxygen studies on the 11th day of the experiment and six days after termination of the acetone injection showed considerably less oxygen production during the second study. Results of the continuous injection experiment were generally inconsistent with results expected on the basis of laboratory studies. Chemostat and respirometer experiments suggested that a possible explanation for

the failure of the acetone to degrade in the model river experiment was a nitrate deficiency. Laboratory measurements of the volatilization coefficients of benzene, chloroform, methylene chloride, and toluene for a range of mixing conditions showed that the coefficients were equal to 0.655 of the oxygen absorption coefficient. Laboratory measurements of the volatilization coefficients of seven low molecular weight ketones showed that the volatilization characteristics were different from those of slightly soluble solutes, with 2-octanone volatilizing most rapidly and acetone least rapidly. Results were consistent, however, with the two-film model. The photometer used for ATP analysis was modified to permit injection of the sample with a disposable tip syringe, thus eliminating cross contamination between samples.

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WR036 UNSATURATED ZONE SOLUTES

PROJECT TITLE: FACTORS DETERMINING SOLUTE TRANSFER IN THE UNSATURATED ZONE

WRD PROJECT NO.: WR 68-036

LOCATION: Topical Research

PROJECT CHIEF: James, Ronald V.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Quality of ground and surface waters often is significantly influenced by chemical and solute dispersion processes of the unsaturated zone. Frequently, it is impossible to predict these influences, because the effects of certain relevant, unsaturated zone factors (e.g. changes in water content or in the nature of solid surfaces) are imperfectly understood and because the current transport modelling methods may not be well adapted to the situations encounteredi n practice. As a result, it may be impossible to assess properly the availability of a given water resource, and to predict the impact of certain human activities and of management upon such availability.

OBJECTIVE: Develop and test experimentally theories and mathematical models of reacting-solute transport, so as to enhance the usefulness of such theories and models in assessing the impact of the unsaturated zone's solute transport on water resources and environment quality. Include in the study chemical reactions involving radioactive nuclides as well as reactions of certain solutes found in industrial and agricultural effluents. In addition, develop mathematical models aimed at managing subsurface water quality.

APPROACH: This work will consist of two phases. First, considering the special conditions encountered in the unsaturated zone, develop new mathematical models, predicting transport of reacting solutes through porous media or at media boundaries. Use theory, numerical methods and controlled experiments. Utilize the interaction between theory and experiment for enhancing the understanding of processes involved. Stress unidirectional tranport. First, consider water saturated systems with slow, steady water flows and a single, essentially equilibrium-controlled chemical reaction. Later, study steady but unsaturated flows, paying special attention to the influence of water content on chemical and disperion parameters. Finally, deal with fast, perhaps transient flows chemical kinetics influences and interactions among several reactions. The second phase of this research concerns the development of groundwater pollutant management models. The models will combine numerical simulation models and management techniques such as linear programming. Initial work will focus upon pollutant-source management in transient one-dimensional systems with linear chemistry. Subsequent investigations will deal with pollutant source management in two-dimensions with non-linear one-component chemical systems. The work will utilize existing simulation models and management models in hope of enhancing joint management and simulation capabilities.

PROGRESS AND RESULTS: Restudied the problem of formulating solute transport analysis for cases influenced by chemical reactions which are controlled by local equilibria. For these cases derived a more fundamental boundary condition than that used previously. Devised a numerical procedure which can utilize such a condition. Carried out successfully a long-column, miscible displacement experiment, which involved non-reactive as well as reacting solutes and a 50 percent saturated soil. The concentration profiles were theoretically reasonable. The fitted dispersion coefficient and the empirical, reaction-related parameter differed considerably from those obtained with a saturated, but otherwise similar flow. Designed, built and started testing a short-column apparatus for studying solute transport through unsaturated soils. Theoretical, computer-based analysis and preliminary experiments indicate that the new method, based on this apparatus makes it possible to attain steady unsaturated water flow and may make it possible, in solute transport experiments, to uncouple the water content and water velocity variables.

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WR044 Dist. of elements, fluvial environ.

PROJECT TITLE: Distribution of elements in the fluvial environment

WRD PROJECT NO.: WR 65-044

LOCATION: Topical research

PROJECT CHIEF: KENNEDY, VANCE C.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: The interaction of water and stream solids, i.e. abiotic material, organic detritus and biota, can affect the chemical composition of both water and solids, especially in the case of minor elements. Thus, when new solutes are added to a stream, they may behave as conservative constituents, may be adsorbed by stream solids (with or without displacement of previously adsorbed materials), may precipitate, or may combine with stream solutes to form complexes having properties quite different from the original solutes. In some respects, stream biota will behave much like abiotic solids on reacting with stream solutes, but in other aspects their behavior may be very different as, for example, in the case of nutrient uptake. A better understanding of the rate and nature of water-stream solids interaction is needed to allow quantitative predictions of the manner of transport of various dissolved constituents.

OBJECTIVE: (1) To determine the nature and rates of the hydraulic and chemical processes involved in the interaction between introduced solutes and abiotic material plus organic detritus; (2) to determine the role of stream biota as chemical substrates in reactions between stream solutes and biota; (3) to determine the response of stream biota to various solutes added to the stream; and (4) to mathematically simulate the transport of stream solutes, taking into account the various components of the stream solids.

APPROACH: Phase I (completion FY 1976) A detailed examination of the compositional variation in water and sediment will be made for several clean streams during storm runoff in an effort to establish general patterns of change. An attempt will be made to relate variations in both major and minor elements to the relative proportions of overland flow, soil interflow and ground water making up total stream discharge. The distribution of trace elements between water and sediment under fresh and brackish conditions will be investigated both in the laboratory and field. Phase 2 Tracers will be injected into small streams to determine the manner of transport for solutes which vary in degree of affinity for bed sediments.

PROGRESS AND RESULTS: A two-month field experiment in Redwood National Park entailing injection of Cl, Br, nutrients Li, Na, K, Sr in a low-nitrate pristine stream was completed early in the fiscal year. Lithium analyses and most Sr analyses have been completed along with some Cl and NO**3 analyses. Five plexiglass channels containing many slides acting as algal substrates were set in the same stream and nutrients added to four of the channels, which were shaded 0, 30, 66 and 94 percent. All four were compared to the control which had no

shade or added nutrients. Maximum biomass was similar in both control and fully lighted treatment channels, but chlorophyll was half as great in the control. Biomass: chlorophyll ratio in the control channel increased throughout the experiment but decreased by half or more in nutrient-treated channels within 4 days. Daylight uptake of nitrate did not increase directly with biomass but decreased with age of the community due to gradual periphyton senescence. These results indicate that cycling distance of biologically important nutrients in a stream reach depends upon input location in a watershed and time elapsed since significant changes occurred in the stream environment. The project chief has spent more than half time helping represent the Survey in Federal planning for acid rain research.

COMPLETED REPORTS:

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Interagency Advisory Committee on Water Data, 1978, Research and monitoring of precipitation chemistry in the United States - Present status and future needs: U.S. Geol. Survey, Office of Water Data Coordination, unnumbered report, 64 p.

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WR046 Geochemistry of Estuaries

PROJECT TITLE: Geochemistry of Estuarine Waters and Sediments

WRD PROJECT NO.: WR 68-046

LOCATION: SAN FRANCISCO BAY, CALIFORNIA

PROJECT CHIEF: PETERSON, DAVID H.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: There are few data on the processes and rates which control changes in water and sediment chemistry in our river, estuary, and coastal-ocean systems. Such information is essential to evaluation of the response of these systems to man's activities which can lead to changes in the amount, character, and timing of the fresh-water, toxic-waste, and nutrient inflows to our estuarine and marine environment.

OBJECTIVE: Define the dominant processes which influence water and sediment chemistry in San Francisco Bay and other estuarine systems.

APPROACH: A systematic field sampling program is done through the year. Physical and chemical properties of the inflow to and water mass within the Bay are determined, including salinity, temperature, and pH of the water, the abundance of dissolved O(2) and plant nutrients, suspended particle and pesticides associated with suspended particles and bottom sediments. These field observations will be combined with and related to parallel investigations and to observations of the phytoplankton productivity, benthic population and water circulation within the estuaries by other investigators. As data becomes available from the field, comprehensive techniques will be used to estimate the rates of (primarily) the nonconservative processes which influence water and sediment chemistry. Where practicable or desirable, studies will be extended to other estuarine systems (Potomac River estuary or others) to test, develop, or use methods and equipment under a wider range of conditions than that found in San Francisco Bay.

PROGRESS AND RESULTS: A 3-dimensional data base of salinity, temperature, and water-chemistry and related parameters, from surveys of the San Francisco Bay system every two weeks during January-December 1980, is being developed. In South San Francisco Bay, an embayment with a large source of waste at the south end, water exchange between channels and shoals is somewhat decoupled. Salinity was depressed in winter by mixing with local fresh-water inflow and with lower-salinity water from the north. Except near major outfalls near the south end of South Bay the dissolved nutrients ammonium, nitrate and silica were depressed to low concentrations (at or near those that limit growth) in spring when major phytoplankton (chlorophyll) development prevailed. Subsequently "red-tides" were observed over some shoals. In North San Francisco Bay river inflow is a major control on water chemistry. Nutrient distributions over shoals are apparently related to magnitude of river flow, to phytoplankton development, and to other factors. Seasonal variations in phytoplankton biomass over shoal areas seem to be related to river

flows and to shallow water depth (i.e., restricted circulation, high average light intensity). During prolonged population growth (weeks) the bottom is probably an important nitrogen and silica source to phytoplankton over the shoals. Study of phytoplankton productivity in San Francisco Bay through sampling and analysis, and concurrent numerical simulation of light-driven phytoplankton productivity, suggest that in partially to well-mixed estuaries characterized by moderate suspended particulate water concentrations and shallow depths, phytoplankton that sink form a phytoplankton maximum (similar to a turbidity maximum but not necessarily in the same location). But in estuaries (or times) of high suspended particulate matter concentrations or deeper depths, phytoplankton that sink cannot maintain themselves to form a phytoplankton maximum.

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Conomos, T.J., Smith, R.E., Peterson, D.H., Hager, S.W., and Schemel, L.W., 1979, "Processes affecting distributions of water properties in the San Francisco Bay estuarine system", in Conomos, T.J., ed., San Francisco Bay, The Urbanized Estuary: AAAS, 40 p.

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Harmon, D.,D. and Cascos, P., 1979, A comparison of seasonal distributions of inorganic nitrate and silicate between shoal and channel zones in Northern San Francisco Bay (abs., EOS, Transactions American Geophysical Union, 1 p.)

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WR060 CIRCULATION, SAN FRANCISCO BAY

PROJECT TITLE: CIRCULATION PATTERNS AND SEDIMENT TRANSPORT IN SAN FRANCISCO BAY AND ADJACENT OCEAN

WRD PROJECT NO.: WR 71-060

LOCATION: CALIFORNIA STATEWIDE

PROJECT CHIEF: CONOMOS, T. JOHN

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: WE MUST ACQUIRE DETAILED KNOWLEDGE OF THE PERTINENT NATURAL FACTORS AND PROCESSES OPERATING IN ANY RIVER-OCEAN MIXING SYSTEM TO OBTAIN A BETTER UNDERSTANDING OF PRESENT CONDITIONS; AND ANTICIPATE RESULTS OF PROPOSED REDUCTION IN FRESH-WATER INFLOW INTO THE BAY SYSTEM.

OBJECTIVE: (A) To determine temporal (tidal, seasonal) variations in the spatial distribtuion of water properties of the inland waters of the San Francisco Bay system and the adjacent coastal ocean; (B) to determine temporal (seasonal) variations in the composition (chemical and mineralogical) and abundance of suspended particles being transported between the inland waters of the San Francisco Bay system and the adjacent coastal ocean; (C) to make semiquantitative estimates of the tidal and seasonal exchange of selected constituents (both dissolved and suspended); (D) to relate these seasonal variations to the dominant natural processes occurring in this system so that the response of the system to changes in pertinent ambient conditions can be predicted.

APPROACH: Using a continuously recording pumping system and discrete bottle samplers, water samples are collected in rapid sequence. Discrete water samples are treated and analyzed for selected chemical and physical parameters and for included organisms and particles. Sediment samples are also collected, and current-meter arrays deployed and recovered. Where practicable or desirable, studies will be extended to other estuarine systems (Potomac River estuary or others) to test, develop, or use methods and equipment under a wider range of conditions than that found in San Francisco Bay.

PROGRESS AND RESULTS: The shallow-water vessel (R/V Estero), fully instrumented (continuous analytical and data-logging functions), is being used intensively (along with the R/V Polaris) to acquire a 3-D hydrographic data base fortnightly (January-December 1980) in the Bay and Delta. These data are being processed, with our own software packages, for almost immediate use by our project scientists. We are continuing to work closely with other projects (WR-68-046, WR-76-140, WR-79-164, WR-77-156) to improve our water collection and analytical methods. Our publishing activities are being highlighted by a second symposium volume, entitled "San Francisco Bay: Use and Protection". This volume is being edited and will be published in summer 1981. It includes a few chapters from our project personnel and is partially funded by a grant from WRD. In addition to this effort, several Open-file reports summarizing our hydrographic and biologic data

collected in the Potomac River (1977-78) have recently been published. Scientific progress involving both participation and support from our project personnel are summarized in Peterson's project description (WR-68-046).

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WR140 Hydrodynamics of a Tidal Estuary

PROJECT TITLE: Hydrodynamic and Mathematical Modeling of Circulation and Transport Phenomena in a Tidal Estuary

WRD PROJECT NO.: WR 76-140

LOCATION: San Francisco Bay area

PROJECT CHIEF: Cheng, Ralph T.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: The ecosystem of a tide-affected estuary consists of an extremely complicated balance of natural processes. Some of the basic characteristics of such a system, for example the San Francisco Bay, are not well understood. Comprehensive description of the hydrodynamics and the related transport processes is still lacking. Better understanding of the effects of interactions among natural processes and human activities on this system requires advances in basic science and in its application to applied problems. Circulation in a tidal estuary is in response to tides, inflow of fresh water, wind, and gravity and density stratification. Topography of the estuary basin, air-water interaction, turbulent mixing, viscous resistance at the bottom, and rotational effects of the earth, together with the above-mentioned driving forces, constitute a very complicated balance that conserves mass, momentum and energy in the system.

OBJECTIVE: Broad goals of this project are to understand processes and rates by which water, solutes and other organisms interact so that the relative importance of river inflow, winds, tides, and other dynamic forces which act on the estuary system can be quantified, and that conceptual and numerical models of these interactions can be developed and verified.

APPROACH: A simple model which preserves the most important features of the hydrodynamic characteristics will be constructed. This computer program will be improved repeatedly to bring secondary mechanisms into the model. A program of collecting hydrodynamic data will provide information for use in calibration of the mathematical model. Other information, such as meteorological data, will also be collected. Modeling concepts and measurement techniques will be modified as necessary to permit most effective construction and use of the model.

PROGRESS AND RESULTS: Collaboration between NOS/NOAA and USGS on an extensive circulation survey of the San Francisco Bay estuarine system began. The survey includes deployment of a large number of current meters and for a long duration, together with some concurrent tidal and meteorological observations. The data set being collected represents a systematic circulation survey of an estuarine system; the data set will aid present and future modeling efforts of the Bay system. Significant progress has been made in data processing. Two independent data translation systems have been made operational to translate magnetic data tapes of Aanderaa Instruments and

Environmental Devices Corp. instruments. During this reporting period, the Project Chief was appointed as a Research Advisor of WRD for solute transport group.

COMPLETED REPORTS:

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WR156 Polaris operations

PROJECT TITLE: Research Vessel Polaris operations in San Francisco Bay and adjacent coastal ocean

WRD PROJECT NO.: WR 77-156

LOCATION: Topical Research

PROJECT CHIEF: Conomos, T. John

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: A stable moving platform is needed to house at least 10 scientists throughout the year (for periods of weeks) so that large volumes of complex and continuous data can be carefully and rapidly collected and precisely measured and analyzed immediately after collection.

OBJECTIVE: To provide scientific platform (research vessel) for estuarine studies, platform functions and measurement, collection, and subsequent analysis of geological, chemical, physical, and biological data throughout the year for extended time periods.

APPROACH: Operating expenses for research vessel including dockage fees, boat maintenance, diesel fuel and food for crew.

PROGRESS AND RESULTS: Continued use of R/V Polaris and R/V Estero for intensive biological, chemical, physical, and sedimentological data collection and analysis in San Francisco Bay and Delta.

WR164 Estuarine plankton dynamics

PROJECT TITLE: Plankton dynamics in tidal estuaries

WRD PROJECT NO.: WR 79-164

LOCATION: San Francisco Bay area, Calif.

PROJECT CHIEF: Cloern, James E.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Because the plankton are important sources of material and energy for other trophic levels, and because they interact rapidly with dissolved solutes, and understanding of plankton dynamics is a prerequisite for understanding other dynamic phenomena in estuaries. The composition and density of plankton populations vary temporally and spatially in response to both natural and man-induced environmental changes. Assessments of man's impact on estuarine ecosystems is thus dependent upon a thorough understanding of the relationships between natural environmental changes and plankton dynamics in unperturbed systems.

OBJECTIVE: This project has three objectives: (1) to monitor standing stock, productivity, and composition of phytoplankton and zooplankton in a large estuarine system so that major patterns of spatial and temporal variation can be defined; (2) to estimate significance of plankton as primary and secondary producers in this system; and (3) to delineate those environmental factors most important in causing observed patterns of variability, and to assess the relative importance of processes that affect density and composition of plankton populations.

APPROACH: These objectives will be approached with an interaction between descriptive and experimental field studies and development of simulation models. Field studies suggest important mechanisms that must be acknowledged by models and provide a data base for model calibration and subsequent verification. Conversely, evolving ecological models suggest processes and environmental factors that deserve particular emphasis by field studies. Feedback between model development and field work will accelerate understanding of the natural system, and should produce ecological models having sufficient realism to allow for prediction of gross effects of man-induced perturbations.

PROGRESS AND RESULTS: During September-October 1979 we documented some chemical and biological consequences of a large sewage spill in South San Francisco Bay (report in progress); this was a unique opportunity to study some chemical consequences of anoxia. Intensively (spatially and temporally) surveyed the San Francisco Bay ecosystem, with emphasis on population dynamics and productivity of planktonic algae and animals. A serious effort is made to store, edit and examine data, using a microprocessor. Significant results resulted primarily from our study of shallow waters of the Bay system where circulation, light and nutrient availability and the importance of sediment processes to the water column differ from in the deeper channel, where

most historical work has been done. Attempted to measure annual primary production in San Francisco Bay; we are partitioning productivity into 3 size classes of organisms to define better those groups of algae most responsible for providing food. Our biological fieldwork is integrated closely with a study of water chemistry and hydrodynamics and is also coordinated with California Fish and Game's study of fisheries. We have begun a study of microalgae in the sediments and find their biomass to be considerable. An interpretive report is in progress that summarizes biological consequences of the 1976-1977 drought; this has implications for future water diversions. Three data reports are near completion. A data report was released summarizing results of biological studies on the Potomac River, 1977-1978.

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CR098 SEDIMENT TRANSPORT PHENOMENA

PROJECT TITLE: MEASUREMENT AND PREDICTION OF SEDIMENT TRANSPORT PHENOMENA

WRD PROJECT NO.: CR 74-098

LOCATION: Topical Research

PROJECT CHIEF: HUBBELL, DAVID W.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: In alluvial streams, for every different hydrologic condition, the bed configuration, sediment transport, and hydraulic characteristic mutually change to achieve a quasi-equilibrium. The changes affect the ability of the stream to convey given quantities of water, accommodate navigation, transport and dilute solid and solute wastes, support aquatic biota, and perform a variety of other similar functions. As yet, the relationships between pertinent hydraulic andsedimentologic variables are not completely understood, hence the extent to which important variables, particularly bed-form roughness and sediment transport,w ill change in response to natural or man-induced alterations to the flow regime can not be predicted with reliability. As a result, optimum utilization and management of a waterway usually is not assured and, often, modifications intendedt o enhance the utility of a waterway are ineffective or have adverse effects.

OBJECTIVE: To provide a more complete understanding of sedimentation phenomena in alluvial streams and the response of such streams to imposed changes through a better understanding of the relationships between hydraulic and sedimentologic variables, particularly (1) The relationships between the factors that most influence the formation and alteration of bed forms and the transport of bedload and bed-material load; and (2) The interrelationships between bed-form characteristics and the transport of bedload and bed-material load.

APPROACH: Initially, existing data will be analyzed to relate bed-form characteristics and hydraulic and sedimentologic variables, and one or more bedload samplers will be developed to permit accurate measurements of bedload transport. Later, data on bed-form characteristics, sediment transport, and other pertinent variables will be collected, as required, to meet specific needs; acoustic instrumentation, including side-scan sonar, will be employed to measure bed configuration and movement, and suitable bedload samplers, as well as suspended-load samplers, will be used to define transport rates. Tracer techniques also may be applied. Finally, data will be analyzed to define criteria for predicting bed form and to provide a better understanding of sediment transport phenomena. Both sand-bed and gravel-bed streams will be studied.

PROGRESS AND RESULTS: Data from six runs with 6.5 mm bed material and two runs with 2.1 mm material in the bedload-sampler calibration facility at St. Anthony Falls Hydraulic Laboratory were analyzed to

determine sampling efficiencies of six versions of the Helley-Smith sampler, the BTMA "Arnhem" sampler, and a modified VUV sampler (not all samplers were used in all runs). Comparisons of average sampled and measured rates showed standard versions of the Helley-Smith sampler had efficiencies well over 100 percent and versions with low nozzle expansions had efficiencies less than 100 percent. This method of comparison is valid only ifr ates from individual samples vary linearly with corresponding actual transportr ates. Data suggest that most samplers have nonlinear relations, hence, data currently are being analyzed in an effort to compare individual sampled rates withe stimates of the actual rates that existed at the time and place of sampling. Estimates of actual rates are obtained by using continuous measurements of bed elevation at the sampling point in conjunction with continuously measured rates att he bedload trap. The project chief served as a member of the A.S.C.E. (1) Sedimentation Committee (Hydraulics Division) and (2) Task Committee on HydrographicI nvestigations on Inland Waterways (Waterway Division), and prepared "Section V--Suspended-Sediment, Bed-Load, and Bed-Material Sampling" of the task committee's report. In previous years, unreported activity included contributing to the preparation of (1) ASTM glossary of sediment terms, (2) ASTM standards on "Sampling sediment in motion," and (3) Chapter 3, "Sediment," National Handbook of Recommended Methods for the Water-Data Acquisition (1978).

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CR102 SEDIMENT MOVEMENT IN RIVERS

PROJECT TITLE: SEDIMENT MOVEMENT AND CHANNEL CHANGES IN RIVERS

WRD PROJECT NO.: CR 75-102

LOCATION: NATIONWIDE

PROJECT CHIEF: MEADE, ROBERT H.

HEADQUARTERS OFFICE: LAKEWOOD, CO

PROBLEM: SEDIMENT MOVES THROUGH RIVER SYSTEMS IN RESPONSE TO SPECIFIC EVENTS AND CHANGING CONDITIONS IN DRAINAGE BASINS. THESE EVENTS AND CONDITIONS ARE BOTH NATURAL (FLOODS, CLIMATE CHANGES) AND ARTIFICIALLY-INDUCED (ACCELERATED EROSION, RESERVOIRS, DIVERSIONS, CHANNELIZATIONS). THE RESPONSE OFTEN TAKES PLACE OVER PERIODS MEASURABLE IN DECADES OR LONGER. THE MORPHOLOGY OF THE RIVER CHANNELS CHANGES AS SEDIMENT MOVES THROUGH THE SYSTEM.

OBJECTIVE: TO ASSESS: (1) CHANGES IN RIVER SEDIMENT LOADS OVER PERIODS OF DECADES OR LONGER, AND THE FACTORS (NATURAL AND ARTIFICIAL) THAT CAUSE THE CHANGES; (2) RATES AT WHICH RIVERS CHANGE THEIR COURSES, SHAPES, AND OTHER MORPHOLOGIC FEATURES, BOTH IN THEIR NATURAL STATE AND IN RESPONSE TO ARTIFICIAL INFLUENCES; (3) EFFECTS OF INFREQUENT CATASTROPHIC EVENTS OR LARGE-SCALE HUMAN INFLUENCES ON THE "EQUILIBRIUM" SEDIMENT MOVEMENT AND CHANNEL MORPHOLOGY IN RIVERS; (4) SOURCES, PATHWAYS, AND SINKS OF SEDIMENT IN RIVERS.

APPROACH: BASICALLY A HISTORICAL APPROACH, USING AVAILABLE RECORDS AND MAKING SOME FIRST-HAND FIELD STUDIES. RECORDS WILL INCLUDE SEDIMENT-LOAD DATA PREVIOUSLY COLLECTED BY USGS AND OTHER AGENCIES; CHANGES IN CHANNEL MORPHOLOGY WILL BE INTERPRETED BY COMPARING OLD AND NEW MAPS PLUS AVAILABLE AERIAL PHOTOGRAPHS OF SELECTED RIVERS IN THE UPPER MISSOURI BASIN. FIELD STUDIES WILL INCLUDE REPEATED SURVEYS OF SELECTED CHANNELS AND TRACER STUDIES OF SEDIMENT MOVEMENT.

PROGRESS AND RESULTS: Studies of sediment carried by the Amazon River of Brazil and Peru have yielded three new conclusions. (1) The mean annual discharge of suspended sediment by the Amazon at Obidos, Brazil, is 800 to 900 million metric tons, an amount twice as large as that reported by previous investigators. (2) Fine grained particles in suspension--at least as fine as 0.01 mm and perhaps as fine as 0.001 mm--are not distributed evenly from the bed of the river to the surface, but are more concentrated near the bed. (3) The sands on the bed of the Amazon, unlike those in other large rivers (e.g., Mississippi), show no decrease in mean grain size in the lowermost 3500 km of river. Effects of the (50-yr) flood of May 1978 were documented in a 90-km reach of Powder River in southeastern Montana. A sediment budget for the flood event was constructed from: (1) Daily suspended-sediment measurements at gaging stations at the upper and lower ends of the reach; (2) Resurveys of channel cross sections that had been established before the flood; and (3) Measured thicknesses of new overbank sediment deposited on the flood plain. Although the flood removed 3-5 million tons of sediment from the channel in the 90-km reach, it added a somewhat larger amount of sediment to the

flood-plain. The net effect of the flood on the valley was aggradation. Studies of the movement and storage of bedload in East Fork River, Wyoming, show that (1) During low-water seasons, movable bed material is stored in distinct and separated areas of the channel that are centered 500-600 m apart and each contain 2 500-3500 tons of bed material; and (2) The mean distance between centers of storage corresponds to the mean distance of bedload transport during a major riseand fall of the river. The relation between bedload transport and water discharge is not consistent but differs markedly from one part of the river to another.

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Meade, R.H., Nordin, C.F., Jr., Curtis, W.F., Costa Rodrigues, F.M., do Vale, C.M., and Edmond, J.M., 1979, Transporte de sedimentos no Rio Amazonas: Acta Amazonica, v. 9, no. 3, pp. 543-547, 4 p.

CR104 REHAB. POTENTIAL, ENERGY LANDS

PROJECT TITLE: RECONNAISSANCE TECHNIQUES FOR EVALUATION OF REHABILITATION POTENTIAL OF ENERGY RESOURCE LANDS

WRD PROJECT NO.: CR 75-104

LOCATION: Rocky Mt., Northern Great Plains, & Southern States

PROJECT CHIEF: Shown, Lynn M

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: HYDROLOGIC INFORMATION WITH RESPECT TO REHABILITATION POTENTIAL IS NEEDED BY LOCAL, STATE AND FEDERAL GOVERNMENTS, PRIVATE LANDOWNERS, ENERGY COMPANIES AND OTHERS PRIOR TO DECISIONS ON THE LEASING, MINING PLANS, AND MINING OF PUBLICLY-OWNED COAL AND OIL SHALE. THE INFORMATION IS NEEDED OVER THE NEXT ONE TO FIVE YEARS, SO RECONNAISSANCE TECHNIQUES MUST BE USED TO OBTAIN MUCH OF THE NECESSARY DATA. THE TWO FACETS OF THE PROBLEM ARE: (1) TO DEFINE THE BASELINE CONDITIONS AS THEY EXIST PRIOR TO MINING MOSTLY IN AREAS HAVING SPARSE HYDROLOGIC DATA, AND (2) TO ASSESS THE POTENTIAL FOR REHABILITATION OF THE LAND-WATER SYSTEM AFTER MINING.

OBJECTIVE: To refine and apply reconnaissance techniques that provide mappable and other easily assimilated information to be used as baseline data and in evaluating the rehabilitation potential of land where energy-resource mining and other land-use changes are proposed, and in development, verification, and application of hydrologic process and regression models. Data to be collected and interpreted include: mean annual runoff, 2-, 5-, and 10-year peak flows, sediment yields, soil-moisture potential relations, bulk density, soil-vegetation-water relations, slope and exposure effects on vegetation and hydrology, reconstruction of topography after assumed mining, channel and hillslope erosion, and channel condition.

APPROACH: The techniques to be used to characterize watersheds of various sizes are (1) Soil-moisture storage associated with vegetation types. (2) Calibration of nuclear moisture measurements. (3) Estimates of annual runoff by subtracting soil-moisture from annual precipitation. (4) Relation of percent bare soil to runoff and sediment yield. (5) Estimates of annual runoff and peak discharges using channel measurements. (6) Estimates of sediment yield using climate, basin characteristics, and reservoir sediment surveys. (7) Erosion monitoring by resurveying monumented transects. (8) Hillslope, channel, and geologic cross-section analysis with respect to topographic reconstruction of potential mine areas. Soil, vegetation, runoff, and erosion of nearby mine spoils in various states of rehabilitation will be investigated.

PROGRESS AND RESULTS: Most progress this year is related to small basin hydrologic modeling studies being conducted cooperatively by six WRD Districts, the rainfall-runoff modeling project (CR77-228) and the BLM EMRIA Program. Our main contributions involve collection and interpretation of data needed to evaluate the hydrology of energy lands and the effects of energy development on the land-water systems.

Research is being done to determine how information obtained about soil-water movement and retention can be used to improve the models. Soil-water relations are particularly important in the Yellow Creek basin, Alabama where, on forested sites, overland flow is practically nil and flood flows result from rapid, shallow ground-water movement. Another finding there was that the deep sandy soils are highly vulnerable to compaction by human or animal traffic. Because of this, six new moisture monitoring sites were also established on croplands of the two basins being modeled in western North Dakota. A vegetation map was prepared, vegetation measurements were made and the effects of vegetation in the hydrologic system were evaluated for the Yellow Creek basin, Alabama. Premining and postmining estimates of soil loss, sediment yield, and streamflow peaks and volumes were made using applicable methods for a 4 km**2 forested tributary basin to Yellow Creek. Sediment surveys of several stock ponds and sampling of the major soil types are planned in the Prairie Dog Creek basin, Montana.

COMPLETED REPORTS:

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CR105 SEDIMENT-HILLSIDE MORPHOLOGY

PROJECT TITLE: Sediment Movement and Hillslope Morphology

WRD PROJECT NO.: CR 65-105

LOCATION: Topical Research

PROJECT CHIEF: WILLIAMS, GARNETT P.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: The bankfull discharge of a stream marks the condition of incipient flooding. Engineers, geomorphologists and others need to be able to predict bankfull discharge at a site, but at present there is no reliable way to do this. The problem, therefore, is to find a dependable way to determine bankfull discharge.

OBJECTIVE: (a) Compare existing methods of estimating bankfull discharge. (b) Develop a good way to estimate bankfull discharge. (c) Examine, with an eye toward prediction, the recurrence frequency of bankfull discharge.

APPROACH: (A) Examine the published methods of determining bankfull discharge and compare them to one another, using basic bankfull-discharge data. (B) Use multiple regression to obtain an empirical equation for bankfull discharge as a function of drainage basin and/or channel characteristics. (C) Tabulate and analyze all available data dealing with the recurrence intervals of bankfull discharge.

PROGRESS AND RESULTS: Draft of report was completed that documents the changes in channel geometry downstream from a number of dams. In August 1980 the project leader went to the University of Upsala, Sweden for six months of lecturing and research.

CR187 BEDLOAD TRANSPORT RESEARCH

PROJECT TITLE: BEDLOAD TRANSPORT RESEARCH

WRD PROJECT NO.: CR 74-187

LOCATION: Topical Research

PROJECT CHIEF: EMMETT, WILLIAM W.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Of all processes operating in river channels, and especially of those of practical concern to engineers and others interested in river channel behavior, perhaps the least knowledge is available regarding the hydraulic and mechanics of bedload transport. Before continuing advances in river channel behavior can be made, some understanding of the behavior of bedload sediment must be made.

OBJECTIVE: (1) Define spatial and temporal variations in bedload transport rate for a single stage of flow; (2) Define change in average magnitude of transport rate over a range in hydraulics of flow; (3) Define change in average magnitude of transport rate over a range in channel geometry; and (4) Analyze the data to evaluate the applicability of available bedload equations, suggest new coefficients for the existing equations, or propose new relations for predicting rates of bedload transport.

APPROACH: To use the conveyor-belt bedload-transport facility on the East Fork River near Pinedale, Wyoming, as a control to evaluate variability factors in bedload transport and to field calibrate the Helley-Smith bedload sampler; to use the calibrated Helley-Smith sampler in the systematic collection of bedload samples, along with the concurrent measurements of streamflow hydraulics, from a variety of sand- and gravel-bed streams; and, within the laws of general physics, stochastically develop emperical relations of bedload transport and interpret the physical significance of the developed relations.

PROGRESS AND RESULTS: Completed field data collection on East Fork River as related to fluorescent tracer study. Daily bedload measurements at frequently spaced sections along a reach of river demonstrate significantly different relations of bedload to discharge from one section to another. Collected and overviewed collection of bedload data from a variety of rivers to provide data base necessary to evaluate universality of East Fork River behavior. Data reduction of 1979 data to usable form is nearly complete.

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CR252 Platte River Hydrology

PROJECT TITLE: Hydrology and geomorphology of the Platte River and their relation to wildlife habitat

WRD PROJECT NO.: CR 79-252

LOCATION: Parts of Colorado and Nebraska

PROJECT CHIEF: Hadley, Richard F.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: The Platte River in Nebraska has been designated a critical habitat area for endangered species. It is necessary to predict how changes in the hydrology and channel morphology in the reach from Sutherland to Chapman, Nebraska, will effect the habitat.

OBJECTIVE: To determine the amount and distribution of streamflow required for preserving the migratory bird habitat.

APPROACH: (1) Correct past sequences of flows to present conditions using USBR water budget model and/or USGS GW-SW model. (2) Develop stochastic model to project future flows and floods for several management alternatives (to be supplied by USBR). (3) For various future flows, predict or establish probability limits for: (a) changes in channel width and extent of unvegetated sandbars; (b) effects on natural meadows; and (c) extent and duration of ice cover.

PROGRESS AND RESULTS: Three major hydrologic processes that are essential for preserving the critical habitat and three natural hydrologic hazards to the habitat have been identified. A number of field studies directed toward finding the functions that describe these hydrologic processes are underway. Statistical analysis and computer simulation of existing data is continuing in order to determine the probability distributions describing the hydrologic hazards for present conditions. Statistical summaries of streamflow data for the Platte River Basin were released to the open-file.

COMPLETED REPORTS:

Petsch, H.E., Rennick, K.B., and Nordin, C.F., Jr., 1980, Statistical summaries of selected streamflow data, South Platte River in Colorado and Nebraska: North Platte and Platte Rivers in Nebraska; U.S. Geological Survey Open-File Report 80-679, 278 p.

CR260 Hydrologic estimating techniques

PROJECT TITLE: Development of improved models for estimating streamflow characteristics and sediment yields of lands subject to surface mining.

WRD PROJECT NO.: CR 80-260

LOCATION: Topical Research

PROJECT CHIEF: Frickel, Donald G.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: In many regions, where mining is anticipated, the hydrologic data base from which to make site-specific decisions is less than adequate. However, the hydrologic characteristics of a site must be defined before regulatory authorities can evaluate mine-permit applications. Most of the technique presently available for estimating streamflow and sediment-yield characteristics have deficiencies that detract from their usefulness. Most regression models relating peak discharges to basin characteristics cannot account for soil and vegetation disturbances that occur during mining and reclamation and, therefore, they cannot be used to estimate postmining discharges which are needed for design of hydraulic structures.

OBJECTIVE: To develop improved techniques for estimating streamflow and sediment-yield characteristics of semiarid areas, both before mining and after reclamation.

APPROACH: The effect of soils and vegetative cover on hydrology becomes significant as the area considered becomes smaller. Thus, these may be extremely important variables for estimating the streamflow and sediment-yields at potential mine sites. The use of soil and vegetation parameters in basin characteristic regression models that estimate streamflow and sediment yields will be investigated. This will include determination of which parameters to use and how to evaluate these parameters for large areas with a minimum of sampling. For postmining hydrology, it is also important to determine if and how rapidly these parameters change during the reclamation period.

PROGRESS AND RESULTS: Equations developed for estimating annual runoff volume and sediment yields from small basins using soil and ground-cover density parameters look promising enough to try this approach with peak discharges. Statistical analysis of erosion pin measurements at hillslope sites iin the Piceance Basin verify that ground-surface elevations at some sites are increasing rather than eroding. Resurveys of 97 channel cross sections and 3 stock ponds were completed in the Piceance Basin. Sediment yields of 0.1 acre-ft/mi**2 or less were measured in the ponds. The only notable changes in channel cross sections occurred on channels that drain oil-shale lease tracts C-a and C-b.

CR261 Sediment Transport Model

PROJECT TITLE: Mathematical Modeling of Sediment Transport and Dispersion in Rivers

WRD PROJECT NO.: CR 80-261

LOCATION: Topical Research

PROJECT CHIEF: Sayre, William W.

HEADQUARTERS OFFICE: Denver, CO

PROBLEM: Mathematical models for predicting the dynamic response of rivers to various natural and manmade inputs are increasingly needed to achieve an optimum balance among society's conflicting demands. Rivers with self-formed, movable boundaries pose an important and challenging sort of modeling problems. There is a special need for two-dimensional (i.e., transverse in addition to longitudinal) transport and dispersion models for sediment that account for the exchange of sediment between suspension in the flow, and storage in and transport along the bed, and also the uptake and release of solutes by sorption reactions.

OBJECTIVE: To improve and continue the development of mathematical models that simulate one- and two-dimensional transport and dispersion of bed-material and wash-load sediment in rivers. Particular attention is focused on the bed-and suspended-load transport, transverse mixing, deposition, bed armoring, scour, and resuspension mechanisms; the accounting procedures for bed composition and level; residence times in the bed; and the uptake and release of solutes by suspended and bed sediments.

APPROACH: This project, building on data and information from several past and ongoing studies to extend and modify existing computer programs and analytical methods, is directed toward solving the continuity and momentum equations for water, and the time-dependent advection-diffusion equations, with appropriate coupling terms, for suspended and bed sediments, and for solutes that may be taken up and released. Available field data together with special studies as needed are used for calibration and verification. Formulation of the governing equations are mainly deterministic; however, stochastic formulations may be adopted for selected mechanisms.

NR081 INTERAGENCY SEDIMENTATION PROJECT

PROJECT TITLE: A STUDY OF MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS

WRD PROJECT NO.: NR 39-081

LOCATION: topical research

PROJECT CHIEF: SKINNER, JOHN V.

HEADQUARTERS OFFICE: MINNEAPOLIS, MN

PROBLEM: KNOWLEDGE OF FACTORS GOVERNING THE MOVEMENT AND DEPOSITION OF SEDIMENT IN STREAMS AND RESERVOIRS IS OF MAJOR IMPORTANCE TO AGENCIES INVOLVED IN DEVELOPMENT OF WATER AND LAND RESOURCES OF THE NATION. A KNOWLEDGE OF THE SEDIMENT DISCHARGE OF STREAMS IS ESSENTIAL TO THE EFFICIENT DESIGN AND OPERATION OF PROJECTS FOR THE STORAGE AND USE OF STREAMFLOW. MOVEMENT OF SEDIMENT ALSO AFFECTS AQUATIC LIFE AND PLAYS A ROLE IN THE TRANSPORT OF CERTAIN TYPES OF CHEMICAL POLLUTANTS. COMPLICITY OF SEDIMENT PHENOMENON ARE SUCH THAT COMPREHENSIVE INVESTIGATIONS ARE ESSENTIAL TO SUPPORT ACCURATE CONCLUSIONS.

OBJECTIVE: TO SEEK SOLUTIONS TO PROBLEMS RELATED TO EQUIPMENT AND METHODS FOR COLLECTING AND ANALYZING SEDIMENT SAMPLES. PROBLEMS INVESTIGATED ARE OF COMMON CONCERN TO TWO OR MORE FEDERAL AGENCIES. THE PROJECT FUNCTIONS AS (1) A CENTER FOR THE DEVELOPMENT OF NEW SAMPLING EQUIPMENT FOR BOTH MANUAL AND AUTOMATIC OPERATION (2) A CENTER FOR PROCUREMENT, TESTING, AND CALIBRATION OF SAMPLING EQUIPMENT FOR SALE TO FEDERAL AGENCIES AND (3) A FOCAL POINT FOR REVIEW OF NEW TECHNIQUES AND ESTABLISHMENT OF STANDARD EQUIPMENT AND METHODS.

APPROACH: A KNOWLEDGE OF HYDRAULIC REQUIREMENTS FOR ACCURATE SEDIMENT SAMPLING IS COMBINED WITH A KNOWLEDGE OF MACHINE SHOP TECHNIQUES, CASTING TECHNIQUES, ELECTRIC CIRCUIT THEORY TO DESIGN NEW AND IMPROVED SAMPLERS. PLANS AND SPECIFICATIONS ARE PREPARED TO ALLOW EQUIPMENT TO BE FABRICATED UNDER CONTRACT. TECHNICAL REPORTS THAT EXPLAIN EQUIPMENT AND OPERATING PROCEDURES ARE PREPARED AND DISTRIBUTED TO ALL INTERESTED AGENCIES. NEW EQUIPMENT IS DEVELOPED AND TESTED UNDER REAL AND SIMULATED FIELD CONDITIONS.

PROGRESS AND RESULTS: Through a range of sediment and water discharge the Helley-Smith bedload sampler was calibrated with 2 mm. sand. Sampling efficiency based on mean transport rates was generally high and the data indicated that it may be a function of instantaneous rate. Instrumentation and data collection procedures are being modified to confirm this conclusion. Two hundred tons of 23 mm gravel are being prepared for the next series of tests. For automatic monitoring of suspended-sediment, a density gage has been coupled to a special system that prepares reference samples for automatically checking gage calibration. The system accuracy has been tested over a wide range of temperatures, sediment concentration and dissolved solids concentration. The D-77 suspended sediment sampler has been modified to operate with a flexible container which extends the operating depth.

WR089 FOREST GEOMORPHOLOGY, PACIFIC COAST

PROJECT TITLE: RATES AND PROCESSES OF EROSION AND SEDIMENTATION IN NATURAL AND DISTURBED FORESTED DRAINAGE BASINS IN THE DOUGLAS FIR REGION OF THE PACIFIC COAST

WRD PROJECT NO.: WR 74-089

LOCATION: PACIFIC COAST, CALIF. AND OREGON

PROJECT CHIEF: JANDA, RICHARD J.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Most of the timber harvested annually from the Douglas-fir region, is taken from virgin forests by clearcutting. Logging and associated road construction significantly increase stream sediment loads, and considerable controversy exists concerning the magnitude and persistence of the impact of present silvicultural practices. Crucial management and legislative decisions concerning forest practices are being made in an atmosphere of considerable public pressure and controversy. Better understanding of the geomorphic processes operating in this region will provide a more rational basis for pending decisions, and permit objective assessment of the effectiveness of practices proposed to mitigate sedimentation impacts.

OBJECTIVE: The overall objective is to understand better natural rates and processes of erosion as well as the magnitude and persistence of man's impact on those phenomena. The relative importance of mass movement and of fluvial erosion in providing sediment to the streams in different parts of the Douglas-fir region especially needs to be quantitatively documented. This project will collate and study isolated pieces of sediment yield data collected by various Government agencies as well as collect new data about processes responsible for observed sediment yields, downstream and downslope impacts of forest practices, and types of sediment transported by streams flowing through areas of differing land use. Special attention is focused on interactions between stream channels, streamside hillslopes, and vegetation.

APPROACH: Available hydrologic, sedimentologic, and slope stability data will be compiled along with factors that control types and rates of erosion processed. Study areas are selected on the basis of available data, personal experience, and inspection of aerial photographs. Erosional phenomena are studied and mapped on aerial photographs and in the field. Landslide activity and channel geometry changes are documented through repeated surveying. Stream sediment loads are measured during storms. Emphasis is given to study sites scheduled to undergo land-use changes, but sites that will remain in a natural state for the foreseeable future are also established as bench-mark stations. Erosion in recently logged basins will be compared with that in less disturbed basins.

PROGRESS AND RESULTS: Continuing analysis of surveyed stake arrays, continuously recording strain gages, aerial photographs, and

borehole casing deformation indicate that four complex landslides in the Redwood Creek basin consist of multiple units that in any given year can move more or less independently of one another. Over longer periods all landslide units interact with one another and influence rates and styles of subsequent movement. Movement in upslope and central parts of landslide units is concentrated along sharply defined lateral and basal failure surfaces, and involves relatively little internal deformation. Materials in downslope parts of these units exhibit more internal deformation. During FY 1980 seasonal and storm-related patterns of pulsating movement were comparable to those observed in FY 1978 and 1979. However, massive removal of lateral support by streambank erosion at Minor Creek earthflow resulted in rates of movement that were much greater than in previous years. Acceleration was more pronounced near the toe of this landslide than at midslope positions. Channel cross-section surveys and sediment discharge records continue to suggest that the upper Redwood Creek Drainage basin is starting to recover from the erosional trauma inducted by high intensity storms and massive clear-cutting between 1950 and 1964. Aggradation and high sediment discharge in the lower Redwood Creek basin, however, continue to damage riparian and aquatic habitat in Redwood National Park. Channel geometry studies were continued in the Bull Run Watershed and a photo-interpretive map of erosional landforms in parts of that watershed was initiated. A study of the surficial deposits cataclysmically emplaced into the Toutle River by the May 18 eruption of Mount St. Helens was initiated. Emphasis to data has been on (1) the emplacement of a 2.5km**3 rockslide-avalanche deposit in the North Fork Toutle River, (2) generation of mudflows, and (3) changes in valley and stream morphology. More than 50 monumented cross-sections have been established to help monitor future channel development.

COMPLETED REPORTS:

Harden, D.R., Janda, R.J., Nolan, K.M., 1978, Mass movement and storms in the drainage basin of Redwood Creek, Humboldt County, California--a progress report: U.S. Geol. Survey open-file report 78-486, 161 p.

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Janda, R.J. and Nolan, K.M., 1979, Road log for day I in A guidebook for a field trip to observe natural and management-related erosion in Franciscan terrane of Northern California for Cordilleran Section of the Geological Society of America, p. VIII-1 - VIII-26

Nolan, K.M. and Janda, R.J., 1979, Recent history of the main channel of Redwood Creek in A guidebook for a field trip to observe natural and management-related erosion in Franciscan terrane of Northern California for Cordilleran Section of the Geological Society of America, p. X-1 - X-16

Nolan, K.M. and Janda, R.J., 1979, Recent history of the surface morphology of two earthflows adjacent to Redwood Creek in A guidebook for a field trip to observe natural and management-related erosion in Franciscan terrane of Northern California for Cordilleran Section of the Geological Society of America, p. XI-1 - XI-10

Nolan, K.M., 1979, Graphic and tabular summaries of changes in stream-channel cross sections between 1976 and 1978 for Redwood Creek and selected tributaries, Humboldt County, and Mill Creek, Del Norte County, California: U.S. Geol. Survey open-file report 79-1637, 38 p

Janda, R.J. and Nolan, K.M., 1979, Geomorphic controls on the form of suspended-sediment transport curves in Abstracts with Programs, Rocky Mountain Section of the Geological Society of America, v. 11, no. 6, p. 275

Janda, R.J., Nolan, K.M., and Stephens, T.A., 1980, Styles and rates of landslide movement in slump-earthflow-sculpted terrane, Northwestern California in Abstracts with Programs, Cordilleran Section of the Geological Society of America, v. 12, no. 3, p. 113

WR138 ARCTIC FLUVIAL PROCESSES, LANDFORMS

PROJECT TITLE: FLUVIAL PROCESSES AND LANDFORMS IN THE ARCTIC--A BIBLIOGRAPHY

WRD PROJECT NO.: WR 75-138

LOCATION: INTERNATIONAL

PROJECT CHIEF: SCOTT, KEVIN M.

HEADQUARTERS OFFICE: Laguna Niguel, CA

PROBLEM: MAJOR CONSTRUCTION PROJECTS IN ARCTIC REGIONS REQUIRE INFORMATION ON THE UNIQUE VARIETY OF FLUVIAL AND SOIL-ZONE PROCESSES THAT AFFECT THE RESPONSE OF THAT ENVIRONMENT TO MAN'S ACTIVITIES. CONSTRUCTION OF ENERGY AND MINERAL RESOURCE DEVELOPMENT PROJECTS, ESPECIALLY IN ALASKA, IS BASED GENERALLY ON READILY AVAILABLE ENGLISH LITERATURE, ON UNDOCUMENTED EXPERIENCES, HURRIED EXPERIMENTS, OR HEARSAY. LITERATURE ON ARCTIC PROCESSES IS LARGE, BUT THE PARTS THAT PERTAIN DIRECTLY TO HYDROLOGIC ASPECTS OF CONSTRUCTION PROJECTS AND ATTENDANT ENVIRONMENTAL IMPACTS ARE SCATTERED THROUGH MANY SOURCES. MOST PROPOSED CONSTRUCTION SCHEMES AND ARCTIC REGION ENVIRONMENTAL STATEMENTS ARE NOT AS COMPLETE OR WELL-DOCUMENTED AS THEY COULD BE IF AN ANNOTATED BIBLIOGRAPHY OF PERTINENT ARCTIC LITERATURE WAS AVAILABLE.

OBJECTIVE: TO PREPARE AN ANNOTATED BIBLIOGRAPHY OF SIGNIFICANT PAPERS DEALING WITH FLUVIAL AND OTHER RELATED LANDSCAPE PROCESSES IN THE ARCTIC. AN EXPECTED EVENTUAL RESULT OF PREPARING THE BIBLIOGRAPHY WILL BE A SYNTHESIS PAPER ON ONE OR MORE SPECIFIC ASPECTS OF ARCTIC-STREAM BEHAVIOR.

APPROACH: PAPERS USEFUL IN ASSESSING EFFECTS OF DEVELOPMENT OF ENERGY AND MINERAL RESOURCES (OIL, GAS, COAL, TIN, COPPER, AND CONSTRUCTION MATERIALS) ON THE HYDROLOGY AND ESPECIALLY ON FLUVIAL EROSION, TRANSPORTATION, AND DEPOSITION OF SEDIMENT WILL BE GIVEN SPECIAL EMPHASIS. THE FORMAT WILL BE SIMILAR TO THAT OF THE ARCTIC BIBLIOGRAPHY EXCEPT THAT (A) THE REFERENCES WILL BE GROUPED BY TOPIC WITH AN ACCOMPANYING TEXT SUMMARY, AND (B) THE SUMMARIES FOR INDIVIDUAL PAPERS WILL BE COMPLETE ENOUGH TO STAND ALONE FOR MOST USES. THE ORIGINAL SOURCES NEED ONLY BE OBTAINED IF DETAILS BEYOND THE ESSENTIAL CHARACTER OF THE PARTICULAR TYPE CONSTRUCTION AND EXPECTED IMPACT ARE NEEDED. GLACIOLOGY & SNOW HYDROLOGY, EXCEPT AS THEY AFFECT FLUVIAL & SLOPE PROCESSES, WILL BE EXCLUDED.

PROGRESS AND RESULTS: Data on sediment transport in several arctic streams were analyzed and the results are being prepared as a chapter in the major report that will summarize the work planned for FY81. Investigation of the subarctic Kenai River has yielded results on bed material movement, forms, and stability in a proglacial setting that are directly applicable to arctic streams and will serve as a foundation for the work planned for FY81. A Professional Paper on the Kenai River has undergone colleague review and will be submitted for approval by August 1980.

COMPLETED REPORTS:

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Scott, K.M., 1978, Effects of permafrost on stream channel behavior in arctic Alaska: U.S. Geological Survey Water-Supply Paper 1068, 19 p.

Scott, K.M., 1978, Effects of permafrost on stream channel behavior in arctic Alaska: U.S. Geol. Survey Professional Paper 1068, p. 1-19, 19 p.

Scott, K.M., 1979, Arctic stream processes--an annotated bibliography: U.S. Geol. Survey Water-Supply Paper 2065, 78 p.

WR153 Stream channel behavior

PROJECT TITLE: Stream channel behavior

WRD PROJECT NO.: WR 76-153

LOCATION: Topical

PROJECT CHIEF: Brice, James C.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Stream channel behavior is defined as changes in the form and position of a channel with time and the response of a channel to natural and man-induced variables. Channel stability, as determined by rates of bank erosion, degradation, or aggradation, is an aspect of behavior. Channel behavior is a potentially important factor in the planning, construction, and protection of bridges and highways; but neither experience with channel behavior nor the means of its assessment have been well enough documented to be of much practical use.

OBJECTIVE: The four phases of the project have separate but related objectives: (1) Countermeasures for hydraulic problems at bridges; to determine kinds of stream behavior that most affect bridges, erosion-control measures most effective in controlling behavior, and response of streams to bridge construction. (2) Stability of relocated stream channels; to determine response of streams to relocation and to identify critical factors associated with stability. (3) Stream channel stability evaluation for highway engineers; to prepare manual of techniques for evaluation and study of channel stability. And (4) Stream channel behavior in relation to channel form; to document behavior of major channel types.

APPROACH: Case histories are to be prepared for selected reaches on streams where bridges have been constructed, where channel alterations have been made, or where good hydrologic and geomorphic information is available. Generalizations are to be made and compared with existing empirical relations that have been proposed to account for channel form and behavior. In phase 1, a group of 225 sites will be studied; in phase 2, a different group of 100 sites; and in phase 4, a composite group of about 400 sites. Data for the case histories will be from field observations, field measurements by tape, and measurements on topographic maps and airphotos.

PROGRESS AND RESULTS: Phase 1: Hydraulic problems at bridge piers occurred at 100 sites and problems at abutments, at 80 sites. Problems are attributed to local scour at 50 sites, to general scour at 55 sites, and to lateral stream erosion at 105 sites. Performance ratings are given for rigid and flexible revetment, for flow-control measures, and for measures incorporated into the bridge. Streams are classified for engineering purposes into five major types, each having characteristics of lateral stability and behavior that need to be taken into account in the design of bridges and countermeasures. Phase 2: In comparison with bank stability of the prior channel, bank stability of the relocated channel was about the same at 45 sites,

better at 28 sites, and worse at 14 sites. Length of natural channel involved in relocation ranges at different sites form 70 to 4,200 m, and the median length is 650 m. Among the critical factors identified as contributing to the stability of relocated channels at specific sites are: growth of vegetation on banks (40 sites); bank revetment (33 sites); and stability of prior channel (19 sites).

COMPLETED REPORTS:

Brice, J.C., and Blodgett, J.C., 1978, Countermeasures for hydraulic problems at bridges, v. 1, Analysis and assessment, 169 p., v. 2, Case histories for sites 1-283, 542 p: Report No. FHWA-RD-78-162, Washington, D.C., Federal Highway Administration, 711 p.

CR103 Drilling Techniques

PROJECT TITLE: RESEARCH OF DRILLING TECHNIQUES AS APPLIED TO HYDROLOGIC INVESTIGATIONS

WRD PROJECT NO.: CR 75-103

LOCATION: NATIONWIDE

PROJECT CHIEF: Weeks, Ed (Acting)

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Great need exists in many hydrologic studies for means to identify hydraulic and transport properties of porous media. Improved techniques for obtaining undisturbed and disturbed geologic samples for laboratory analyses and for conducting isolated zone tests by use of inflatable packers are needed to support these efforts.

OBJECTIVE: To develop methods of obtaining the best quality and quantity of undisturbed cores and lithologies by experimenting with rotary (wireline, etc.) drive (various types of barrels), stationary piston, and hydraulic push (shelby-tube, etc.) coring; to determine the most efficient use of various types of drilling muds under any drilling conditions encountered and the relationship of hole size and lithologic conditions to borehole geophysical logging, using air or mud, rotary or auger drilling; and, to determine the most efficient use of pneumatic and hydraulic packers for aquifer testing in shallow depths (1,000 feet) and for hydrofacing or deep testing (in excess of 1,000 feet).

APPROACH: Place special emphasis on collection of cores and samples that are adequate for laboratory analyses, and evaluation, adaptation, and design of new and existing tools for isolated aquifer testing. This would involve drilling techniques, evaluation of existing core barrels, the physical and chemical properties of drilling muds and additives according to their abilities to prevent invasion of samples material, techniques for holding drill holes open for geophysical logging, and a very detailed look at mud-rotary drilled holes. An important function of this effort would be providing consulting and advisory assistance to our field offices. All effort should be closely affiliated with Borehole Geophysical Research Project. All final testing will be done in the field and all methods will have transfer value to other field projects.

PROGRESS AND RESULTS: Experiments on core-drilling alternately hard and soft layers of sand, consolidated limestone, and clay were completed in the coastal plain of North Carolina, and a new drilling technique was developed that substantially improved core recovery compared to conventional techniques. Coring experiments were also conducted in the Denver Formation, consisting of shale, siltstone, and conglomerate, at the Denver Federal Center. These experiments resulted in 99 + percent core recovery. Isolated aquifer test experiments were conducted at the Papago Indian Reservation, Arizona to determine zones transmitting high-arsenic water.

CR128 Hydrologic Instrumentation

PROJECT TITLE: HYDROLOGIC INSTRUMENTATION

WRD PROJECT NO.: CR 57-128

LOCATION: Topical Research

PROJECT CHIEF: GHERING, GARTH E.

HEADQUARTERS OFFICE: Denver Federal Center, Lakewood, CO

PROBLEM: Throughout WRD many projects underway require development of special instrumentation to provide precise data in useable format; providing such data is particularly difficult and often requires special techniques and the development of special instrumentation where deep test wells must be drilled and tested to obtain water-level, direction and quantity of flow within different zones and aquifers, and water samples for obtaining water quality data. Also, because many projects and professional and subprofessional employees throughout WRD are involved with the above outlined problem, there is a need for special in-house centralized instrument calibration and repair facilities needed to insure uniformity of data. National Bureau of Standards criteria for these instruments must be met in some cases.

OBJECTIVE: This project is designed to provide, from a central location, help in solving the problem outlined above, and to provide a centralized pool of experienced talent and capability to accomplish the special data-collection problems faced by other researchers.

APPROACH: Design, construct, and in some cases, operate the necessary special instrumentation pertinent to WRD research problems; provide qualified personnel to operate the special instruments in assistance to other research projects.

PROGRESS AND RESULTS: Completed instrumentation at NRTS, Idaho Falls, Idaho, as related to finite ground-water levels and air-permibility studies. Completed thee ngineering on interface units that apply to Earthquake Prediction Project.

CR104 Borehole Geophysics

PROJECT TITLE: BOREHOLE GEOPHYSICS AS APPLIED TO GEOHYDROLOGY

WRD PROJECT NO.: CR 64-140

LOCATION: Topical Research

PROJECT CHIEF: KEYS, WALTER S.

HEADQUARTERS OFFICE: Denver, CO

PROBLEM: Borehole Geophysics is an essential tool in quantitative hydrogeology. Improvements in analytic techniques and equipment for borehole data offer the possibility of greatly improved accuracy from hydrologic model studies in such important application areas as aquifer yield, water quality, waste disposal, and geothermal power production. Borehole techniques also provide data on undisturbed environments and larger sampling volumes which cannot be achieved from core specimens, and offer direct means for identifying fracture permeability as required in many of the applications cited above.

OBJECTIVE: The objectives of this research project are: to investigate, appraise, and report on the current and potential applications of borehole geophysics in ground-water hydrology, to demonstrate the value of these techniques in various ground-water environments, to adapt existing equipment for hydrologic purposes and to improve methods of quantitative log interpretation. Borehole Geophysics will be applied to the development of energy sources, such as, geothermal, coal, subsurface waste disposal, and artificial recharge.

APPROACH: Techniques and equipment are being developed and field tested in each of the following research areas: (1) improved quantitative log interpretation based on the acquisition of more complete data along with detailed models of sampling volumes and detector geometry; (2) digital techniques for the rapid processing of large data quantities both in the lab and in the field; and (3) advanced equipment capable of operating in a wide range of borehole environments while compensating for such effects as background radiation, borehole fluid properties, and borehole diameter.

PROGRESS AND RESULTS: Results from last yr: Geothermal: Testing of a high temperature acoustic velocity probe was initiated. Results of data obtained from a small diameter core hole in granitic rocks indicate that the presence of hydraulically conductive fractures affect wave energy arriving at approximately shear wave velocity and as a borehole wall tube wave. If the hole size effect can be overcome, this will be a very valuable technique to aid in the understanding of geothermal reservoirs. Acoustic televiewer logs were made in two Raft River wells, where attempts were made to stimulate production by hydraulic fracturing. The logsw ere of significant value in identifying the location, orientation, and character of the fractures produced intentionally and accidentally during drilling. Quantitative analysis of flowmeter data recorded during an injection test at Raft River was completed. Waste Disposal: Theoretical and experimemtal

techniques have been developed to determine the attenuation coefficient and build-up factors of materials to maximize the accuracy of gamma spectral analyses in boreholes. Gamma spectral data obtained at the calibration pits in Grand Junction, Colorado, were used to check the accuracy of a theoretical model of probe response. Theoretical model curves for a variety of cases have been calculated for gamma spectral data and were used in the evaluation of data obtained at the calibration pits in Grand Junction. A catalogue of theoretical model curves has been started. The analysis of field data from Granite Mountain Number 2, located in Wyoming, is being carried out using the results of calibration curves calculated from the computer program model. Tests were made to determine the effects of a centralized probe versus a decentralized probe in collecting in situ gamma spectral data. It was determined that for hole diameters of less than 4.5 inches, the differences are negligible, but for 12-inch hole diameter, differences of 30 percent are encountered. Computer models have been applied to delineate the parameter ranges for the acoustical investigation of the competent lithologies which are most relevant to the waste disposal applications. The analysis has been checked by comparison with waveforms obtained in experimental boreholes involving massive sandstones and fractured granite. The results are being used to begin the search for interpretation techniques which can resolve fracture response from the effects of variable lithology. A research contract for a compensated neutron porosity probe was completed, and testing of the probe in the laboratory was carried out.

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defining the physical characteristics of the Raft River Geothermal in Reservoir, Idaho: Geophysics v. 44, no. 6, June, p. 1116-1141, 1 p.

MacCary, L.M., 1978, Interpretation of well logs in a carbonate aquifer: Water Resources Investigations 78-88, U.S. Geol. Survey, 30 p.

CR202 Nuclear Hydrology Services

PROJECT TITLE: Nuclear Hydrology Services

WRD PROJECT NO.: CR 77-202

LOCATION: Topical Research

PROJECT CHIEF: Wilson, William E.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: During the planning and conduct of nuclear-weapons tests, and for an indefinite period of monitoring sites of past tests, DOE and other Federal agencies and contractors encounter unforeseen problems and frequently recognize unscheduled, usually short-term needs for expert advice in hydrologic matters. As principal hydrologic investigator and advisor to DOE, and because of its decades of experience at nuclear-test sites, the Nuclear Hydrology Program has the contractual responsibility to assist in these matters. Examples include coordination of other DOE-funded projects and reporting hydrologic features of test areas as required by the test-limitation on treaty with USSR.

OBJECTIVE: Provide support on a continuing basis to DOE, DOE contractors, and other agencies in hydraulic testing, areal hydrology, hydraulics and geochemistry; in coordinating WRD projects funded through DOE Nevada Operations Office; in participating in the design and reviewing the adequacy of radiohydrologic monitoring at Nevada Test Site and other nuclear-test areas; in engineering investigations such as inflow to mined chambers and alleged damage to wells by explosions; and in assistance in solving other problems that are incidental to but necessary to the continued development of the nation's defense capabilities.

APPROACH: Coordination of DOE/NV-funded WRD projects is accomplished by daily contact with project chiefs, by distribution of DOE/NV funding, by allotting of pooled technician and clerical services and of technical equipment, and by periodic reporting to DOE/NV of Nuclear Hydrology Program activities and accomplishments. Approach to technical problems varies according to nature of problems but usually involves short-term assignment of project personnel to compile and interpret information from project files or to perform investigations, as in well-damage studies.

PROGRESS AND RESULTS: Continued to provide support to DOE/NVOO as requested. Participated in ad hoc committees such as the Tatum Dome Advisory committee.

COMPLETED REPORTS:

Dudley, W.W., Jr., Ballance, W.C., and Glanzman, V.M., 1977, Hydrology in the Environment of Amchitka Island, Alaska, M.L. Merritt and R.G. Fuller, Eds.: U.S. Energy Research and Development Administration TID-26712, p. 35-51

CR203 Yucca Flat Hydrology

PROJECT TITLE: Hydrology of Yucca Flat, Nevada Test Site

WRD PROJECT NO.: CR 77-203

LOCATION: Southern Nevada (Nevada Test Site)

PROJECT CHIEF: Doty, Gene C.

HEADQUARTERS OFFICE: Mercury, NV

PROBLEM: Underground testing of nuclear explosives has emplaced radioactive elements in the subsurface of Yucca Flat, both above and below the water table. In order to predict migration of contaminants, it is first necessary to determine the detailed hydrogeology, distribution of recharge, potentiometric field in 3 dimensions, and boundary conditions of the basin.

OBJECTIVE: The objective of the proposed work is to understand hydrologic features of Yucca Flat in sufficient detail to predict movement of ground water in this basin. This includes the determination of the following: (1) Points of recharge to the zone of saturation. (2) Configuration of the water table, changes in head within the saturated zone, and the potentiometric head in the underlying regional aquifer. (3) Directions and, where possible, velocities of ground-water flow. (4) Extent to which nuclear testing has modified hydrology, chemistry, or radiochemistry.

APPROACH: Compile existing hydrologic and pertinent geologic data from published and unpublished sources, while concurrently performing the following: measure potentiometric heads in new holes drilled by other agencies; conduct aquifer tests and collect water-quality samples in holes made available; measure recharge to a fissure on Yucca playa; observe recharge in subsidence craters; drill test holes and observe soil-moisture variations. Planned report will integrate past and future data to describe the unified hydrology of Yucca Flat.

PROGRESS AND RESULTS: Inflow measurements to Yucca Crack were discontinued in August 1977 following washout of structures. Total of 3,390,000 ft**3 water entered rack from October 74-August 77. Report in preparation. Instrumented 5 collapse sinks on Yucca Flat for inflow modeling. Tritium content and water-level fluctuations during pumping were monitored in UE2ce. Tritium was nearly stable at 1.64x10**-2 uCi/cm**3 when water level drew down to pump intake. Montoring will continue after water level recovers. Monitoring of tritium content and water-level fluctuations in UE7ns were carried out. Tritium content was below detection. Instrumentation to monitor five collapse depressions was completed at SDS in area 3. Studies of hydrogeology and water chemistry were continued.

CR204 NTS Tracer Studies

PROJECT TITLE: Tracer Studies of Ground-Water Movement at the Nevada Test Site

WRD PROJECT NO.: CR 77-204

LOCATION: Southern Nevada

PROJECT CHIEF: Wilson, William E.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: More than 90 nuclear explosions have been detonated below the water table at NTS. Tracer studies in fractured carbonate and volcanic rocks on and near the Test Site may increase our understanding of radionuclide migration from explosion sites. In addition, there is a need to develop a single-well test to determine aquifer parameters in holes of opportunity because of the great expense to drilling holes especially for this purpose. Tracer studies also offer an insight into the hydrodynamics of fractured rocks.

OBJECTIVE: The basic objective of the proposed project is to gain knowledge in determining hydraulic properties, dispersion, and sorption characteristics in rocks draining the Nevada Test Site through use of tracer tests. Results of previous tracer experiments will be examined and analyzed with the final objective to determine transport characteristics in ground water at Nevada Test Site.

APPROACH: Analyze results of previous tracer tests. Write report on single-well sulfur-35 tests. Write report comparing bromide and tritium as tracers in 2-well test. Digitally model 2-well tritium and bromide test and 2-well sulfur-35 test and write reports.

PROGRESS AND RESULTS: Complete analysis from previous tracer experiments. Digitally model results, testing the hydraulic and chemical parameters. Write reports.

CR207 Radionuclide Migration at NTS

PROJECT TITLE: Radionuclide Migration near Nuclear Explosion Sites, Nevada Test Site

WRD PROJECT NO.: CR 77-207

LOCATION: Southern Nevada (Nevada Test Site)

PROJECT CHIEF: Wilson, William E.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Approximately 90 nuclear devices have been exploded beneath the water table at Nevada Test Site. Although dissolved radionuclides have been identified in water collected from explosion cavities, the lack of documented migration of explosion-derived nuclides other than tritium has led to some complacency that the most hazardous contaminants are retained indefinitely at explosion sites. The mobility or immobility of specific radioisotopes must be documented by controlled field experiments at and near explosion sites.

OBJECTIVE: Determine the degree of mobility of specific radionuclides in the natural media of Nevada Test Site. USGS/WRD objectives in the first of at least two experiments are: (1) determine the hydraulic properties of alluvium in the vicinity of the Cambric explosion site in Frenchman Flat; (2) characterize the chemical quality of water and the changes resulting from the explosion; and (3) select a location and supervise construction and pumping of a well near the Cambric site. An additional objective is to identify sites for similar experiments in other media. (See (15) General Remarks).

APPROACH: At the site currently being investigated and at future sites, the approach will be: (1) review of hydraulic and hydrochemical data to determine the probable natural characteristics; (2) drill through the collapsed rubble above and in the explosion cavity and pump water at several depths to determine chemical, radiochemical, and hydraulic properties; (3) pump water from a well located 3 to 5 cavity radii from the explosion point and sample for chemical and radiochemical analysis; (4) model the flow field and interpret data in terms of the model; and (5) prepare reports on experimental methods and results.

PROGRESS AND RESULTS: A total of 4.16 x 10**6m**3 of water have been pumped from RNM-2S, a satellite well to Cambric Reentry site. A tritium breakthrough occurred about December 1977 and concentrations have steadily increased from below detection levels of 480 to 2.57 x 10**6 pCi/L without any indication of reaching a plateau. Quality of water samples from RNM-2S are very steady. A continuous record of water levels in three observation wells, including the pumped well, indicate near steady-state conditions. Several pumping tests have been analyzed using inverse techniques on a r-z finite element model.

CR208 Radiohydrology of Explosion Sites

PROJECT TITLE: Radiohydrology of Nuclear Explosion Sites at NTS

WRD PROJECT NO.: CR 77-208

LOCATION: Southern Nevada (Nevada Test Site)

PROJECT CHIEF: Wilson, William E.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: The migration of hazardous radionuclides in ground water as a result of nuclear testing beneath the water table is of concern to the Weapons and Plowshare programs and to the investigation of radioactive-waste disposal sites. Parameters essential for modeling the migration of radionuclides within rubble chimneys are the source term, the initial radionuclide distribution, the mobile radionuclides, groundwater infill rates and the chemical and radiochemical changes in ground water as functions of time, temperature, and stage of filling.

OBJECTIVE: In selected reentry holes, the concentration and columetric distribution of dissolved radionuclides will be analyzed during various stages of filling with ground water. This will be accomplished until the potentiometric head has returned to equilibrium and radionuclides have the potential to migrate in the direction of the ground-water gradient. The hydraulic properties of rubble chimneys and the surrounding rocks will be calculated giving an understanding of the mechanism of infill. Included are determining the effects of temperature on hydraulic behavior.

APPROACH: At expended sites where chimney infill is expected to be rapid, reentry holes will be completed to allow retrieval of water samples for chemical and radiochemical analysis and to accommodate downhole instruments to monitor temperature and chimney infill. Representative samples of water will be obtained by pumping when selected zones in the chimney have filled with ground water. During these periods of pumping the hydraulic properties of these zones will be calculated utilizing drawdown and recovery data.

PROGRESS AND RESULTS: Water levels around U19v continue to rise; however, temperatures in the lower regions remain too hot to allow perforation near the bottom of the reentry hole. A suite of logs have confirmed that leakage is occurring through a plug in the reentry casing, causing a high tritium concentration in the hole. Closed hole conditions remain unchanged at U20n. At Faultness, ground water inflow is rising at a rate of 0.12 meters per day and water levels are about 260 meters below preshot levels. Maximum tritium concentrations are in excess of 10**8 pCi/L.

CR226 Paradox Basin Hydrology

PROJECT TITLE: Paradox Basin Hydrology

WRD PROJECT NO.: CR 77-226

LOCATION: Southeastern Utah, Southwestern Colorado

PROJECT CHIEF: Whitfield, Merrick S.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Hydrologic information is not available in usable form to (1) evaluate the Paradox Basin for terminal radioactive-waste storage and (2) develop site data at the Salt Valley Anticline, Utah, for a detailed hydrologic description of a storage site.

OBJECTIVE: (1) Perform hydrologic reconnaissance of the Paradox Basin to aid in understanding the flow system of the area. (2) Hydraulically test and evaluate the salt beds of the Salt Valley Anticline and other lithologic units for hydraulic continuity and hydrologic properties.

APPROACH: Compile existing information in usable form. Collect new data on ground-water levels, spring discharges, and water quality, including base flow of Colorado and Green Rivers. Combine with geologic information to describe at reconnaissance level the movement of ground water in the Paradox Basin. Perform hydraulic tests in wells in Salt Valley to determine hydraulic properties of the salt and of overlying and underlying units. Construct and test additional holes to define relation of local Salt Valley system to Paradox Basin flow.

PROGRESS AND RESULTS: Six test wells were completed and tested in Salt Valley by the end of FY80. The first reconnaissance report completed indicates that upper and lower ground-water systems exist which are separated by a thick sequence ofs alt beds. The principal element of ground-water outflow from the upper aquifers ystem is subsurface outflow to the Colorado and Green Rivers. Only surface flow occurs in the lower aquifer system, as recharge and discharge occur outside the study area. Salt solution in this area probably occurs at a very low rate as no brines have been identified as outflow in the biosphere.

COMPLETED REPORTS:

Rush, F.E., Hart, I.M., Whitfield, M.S., Giles, T.F., and D'Epagnier, T.E., 1980, Results of hydraulic tests in wells DOE-1, -2, and -3, Salt Valley, Utah: U.S. Geol. Survey Open-File Report 80-205, 33 p.

CR231 NTS Waste Sites

PROJECT TITLE: Hydrologic evaluation of potential sites for storage of radioactive wastes at Nevada Test Site

WRD PROJECT NO.: CR 78-231

LOCATION: Nevada Test Site and vicinity, Nevada

PROJECT CHIEF: Doty, Gene C.

HEADQUARTERS OFFICE: Mercury, NV

PROBLEM: Before highly toxic radioactive wastes can be disposed of in geologic formations, it is necessary to describe in great detail the present hydrologic system and potential system under pluvial climates at and near sites under evaluation.

OBJECTIVE: Determine the spatial subsurface distribution of head, permeability, porosity, and rock and water chemistry in areas of the Nevada Test Site that are candidate areas for handling or disposal of nuclear wastes. To assess the potential for flooding in selected areas where nuclear wastes might be stored temporarily on the surface.

APPROACH: The first objective will be met by detailed measurements of hydrologic parameters in exploratory holes by means of pumping tests and other tests conducted in vertical intervals isolated by inflatable packers. Head distribution during pluvial cycles will be determined by identification, sampling, and dating carbonate deposits associated with pluvial springs and by mineralogic evidence of higher water tables in cores from exploratory holes. The second objective will be met by comparison of maximum historical floods for similarly sized basins with the flow capacities of existing channels.

PROGRESS AND RESULTS: Completed reconnaissance of flow path between Nevada Test Site and discharge area for pluvial spring mounds; report in preparation. Continued to develop criteria for sample of playa materials for geochemical evaluation. Completed analysis of flood potential of Topopah Wash and tributaries. Participated in hydraulic testing of geologic test hole on Yucca Mountain.

CR232 Waste Management off NTS

PROJECT TITLE: Hydrologic suitability for nuclear-waste isolation in granitic, clayey, or tuffaceous rocks in Nevada off the Nevada Test Site (NTS)

WRD PROJECT NO.: CR 78-232

LOCATION: Most of Nevada and Death Valley, Calif.

PROJECT CHIEF: Weir, James E., Jr.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Definition of the regional hydrology of areas in Nevada off NTS where rocks are exposed that are considered to be suitable for long-term (about 0.25 million years) storage of nuclear wastes is necessary. Favorable hydrologic attributes must be considered in conjunction with other features in choosing the most ideal sites for further investigation. These attributes include long flow paths to discharge areas, low permeability, and deep water tables.

OBJECTIVE: The initial objective is to provide the hydrologic basis for a preliminary screening of prospective storage sites to assist in the selection of sites having the greatest potential as repositories. The ultimate objective is a comprehensive hydrologic appraisal of at least one repository site selected from several in this study.

APPROACH: (1) Research available hydrologic literature and compile a hydrologic map (1:500,000) of Nevada. (2) Prepare hydrologic appraisals to accompany reports on outcrop inventories of granitic, clayey, and tuffaceous rocks. (3) Assist in defining areas that are most favorable for waste storage. (4) Make reconnaissance of favorable sites selected as an aid to determining requirements for additional hydrologic study. (5) Conduct additional hydrologic study of ground-water flow systems of five southern counties in Nevada, where these systems relate to potential repository sites in tuffaceous and granitic terranes.

PROGRESS AND RESULTS: Reports completed for granitic and clay-rich rock terrains reveal several localities that probably are geohydrologically suitable for waste storage. Four granitic localities have been tentatively selected for further, more detailed study. At least three sites that are dominantly clay-rich rock or tuff appear to be suitable for further study to define waste-repository potential. Progress planned for later in FY80 includes additional age dating of water in the Pahute Mesa ground-water flow system.

CR246 NV Waste Coordination

PROJECT TITLE: Coordination of Hydrologic Investigations of Nevada for Storage of Radioactive Wastes

WRD PROJECT NO.: CR 78-246

LOCATION: Administrative

PROJECT CHIEF: Wilson, William

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: The Water Resources Division (WRD) and several branches of Geologic Division are participating in a major interdisciplinary effort to evaluate the suitability of southern Nevada for disposal of radioactive wastes. Coordination of WRD work within the Survey is necessary on a continuous basis. Investigations related to the ultimate safety of a waste repository must be conducted in accordance with strict quality-assurance requirements.

OBJECTIVE: To provide continuous coordination among investigations of the WRD insofar as they relate to the waste-disposal programs of DOE's Nevada Operations Office. This coordination is to include all aspects of programming, budgeting, data collection, and interpretation and reporting of results. An additional objective is to assure that quality-control procedures are adequately followed and documented.

APPROACH: Coordinate on a continuous basis all aspects of the WRD investigations, assuring that these investigations are adequately planned, funded, operated and reported and that they are focused on obtaining information pertinent to the safe establishment of radioactive-waste repositories. Prepare a quality-assurance plan to comply with provisions of 10CFR60 and other regulations insofar as they apply to waste repositories and monitor compliance with this plan.

PROGRESS AND RESULTS: Assembled and submitted progress reports of investigations on a weekly, monthly, quarterly, and semiannual basis.

COMPLETED REPORTS:

Dudley, W.W., Jr., 1977, Suitability of Nevada Test Site for terminal storage of radioactive wastes (abs.), Geol. Soc. America Abs. with Programs, v. 9, no. 7, pp. 957-958.

U.S. Geol. Survey, 1978, NTS Terminal Waste Storage Program Plan for FY1978: U.S. Dept. Energy, Nevada Operations Off., 122 p.

NR035 Role of Confining Clays

PROJECT TITLE: TRANSPORT PROPERTIES OF NATURAL CLAYS.

WRD PROJECT NO.: NR 65-035

LOCATION: Topical Research

PROJECT CHIEF: WOLFF, ROGER G.

HEADQUARTERS OFFICE: RESTON, VA

PROBLEM: HYDROLOGIC STUDIES CONCERNED WITH THE FOLLOWING PROBLEMS: WATER SUPPLY, UNDERGROUND WASTE DISPOSAL, RECHARGE, MOVEMENT OF CONTAMINANTS, GAS STORAGE, AND SUBSIDENCE, ARE OFTEN HAMPERED BY THE DEARTH OF RELIABLE INFORMATION REGARDING THE EFFECT OF FINE-GRAINED LAYERS. THE PROPERTIES OF INTEREST REGARDING THESE LAYERS ARE: HYDRAULIC CONDUCTIVITY, STORAGE COEFFICIENT, EXCHANGE CAPACITY AND OSMOTIC EFFICIENCY. CLAY MINERALS CONTROL THESE PROPERTIES. AT PRESENT THESE PROPERTIES ARE DIFFICULT TO PREDICT AND/OR MEASURE IN THE FIELD OR ON UNDISTURBED SAMPLES IN THE LABORATORY.

OBJECTIVE: THE OBJECTIVES OF THIS PROJECT ARE TO CONTINUE DEVELOPMENT OF MEANINGFUL MEASUREMENT TECHNIQUES FOR USE IN THE FIELD AND LABORATORY DETERMINATION OF THE PROPERTIES OF INTEREST IN FINE-GRAINED MATERIALS, AND CONCURRENTLY TO INCREASE THE LABORATORY EMPHASIS ON DELINEATING THE FACTORS WHICH AFFECT OR CONTROL THESE PROPERTIES WITH THE GOAL OF IMPROVING PREDICTIVE ABILITY BASED ON RELATIVELY EASILY ACQUIRED DATA.

APPROACH: COMPLETE A THOROUGH EVALUATION OF TWO COMPLETED FIELD AND LABORATORY STUDIES RESULTING FROM THIS PROJECT IN CONJUNCTION WITH THE RESULTS OF AN ADDITIONAL SIMILAR STUDY, TO BE PUBLISHED SOON, AND OTHER DATA AND RESULTS FROM RELATED STUDIES TO DETERMINE THE LOGICAL SEQUENCE OF EMPHASIS TO ACHIEVE THE OBJECTIVES CITED.

PROGRESS AND RESULTS: Tested hypotheses that non-steady techniques could be used to analyze laboratory hydraulic conductivity determinations for "tight" samples (less than 10 **-7 cm/sec). Analytic solutions available are too insensitive to early time pressure changes to permit sensitive determination. Initiated and completed compilation of available data regarding porosity, permeability, distribution coefficients, and dispersivities of rocks.

COMPLETED REPORTS:

Keys, W.S., Wolff, R.G., Bredehoeft, J.D. Shuter, E., and Healy, J.H., 1979, In-Situ Stress Measurements near San Andreas Fault in Central California: Jour. Geophys. Research, v. 84, p. 1583-1591, 8 p.

SR042 Geopressured-Geothermal Resources

PROJECT TITLE: Geopressured-geothermal resources of the United States

WRD PROJECT NO.: SR 73-042

LOCATION: Geothermal Research

PROJECT CHIEF: Wallace, Raymond H., Jr.

HEADQUARTERS OFFICE: NSTL Station, MS

PROBLEM: Super-heated water present in deep sedimentary basins under high fluid pressures, and containing dissolved methane, is a potential energy resource. Knowledge of the extent and of the hydrogeology and chemistry of regional aquifer systems that contain this resource is necessary for a quantitive appraisal of the resource and determining the feasibility of its large-scale development.

OBJECTIVE: To describe, analyze and interpret the hydrogeology of over-pressured deep sedimentary basin deposits in the United States. To identify and map the aquifer systems and their structural controls (faults, etc.). To determine the hydraulic characteristics of the aquifers; the significant hydrodynamic controls; the chemistry and salinity distribution of interstitial water; and the geothermal regime. To utilize innovative approaches to describe over-pressured zones leading to quantitative modeling attempts to appraise their potential as sources of energy.

APPROACH: Geologic framework and aquifer-aquitard relations will be described for promising regional and local geopressured-geothermal areas, beginning with the northern Gulf of Mexico basin (onshore and offshore). Structure maps and geologic cross-sections will be constructed primarily from petroleum industry geophysical well logs and seismic data to show aquifer-aquitard systems and boundary faults. Petroleum industry data will be used to map, describe, and explain distribution of pressure, temperature, and chemical quality in formation waters. Physical, chemical and reservoir properties will be analyzed and interpreted to quantitatively evaluate and estimate the resource. Techniques and methodology will be documented.

PROGRESS AND RESULTS: More than three million curve feet from geophysical logs of twenty deep Gulf Coast wells have been digitized. About half of these wells were analyzed using the sophisticated LOGCALC system of computer programs to obtain reliable calculations of rock and fluid properties to supplement measurements currently in computer files. A new computer program for calculating salinity from geophysical well logs was developed with the assistance of contract personnel for use with the LOGCALC system. These data will be used in computer models to predict reservoir behavior and estimate the amount of geopressured-geothermal energy recoverable from selected reservoirs. One such model will be based upon the nearly completed detailed investigation of the upper Cretaceous Tuscaloosa formation. Another will be based upon a detailed investigation of the Cameron Prospect, Offshore Louisiana and Texas, presently underway. The

Cameron Prospect is discussed in a paper by Wallace entitled, "Distribution of geopressured-geothermal energy in reservoir fluids of the northern Gulf of Mexico basin", published in the proceedings of the fourth U.S. Geopressured-Geothermal Energy Conference. Four additional offshore prospects are also discussed in the paper. Seven geopressured-geothermal test wells have been sampled to date for naturally occurring radionuclides in an effort to determine if shales dewater during fluid production. A paper entitled "**234 u and **238 u context of brine from geopressured aquifers of the northern Gulf of Mexico basin," was prepared by Kraemer with the preliminary conclusions that the brines have very low uranium concentrations and activity ratios only slightly greater than unity.

COMPLETED REPORTS:

Wallace, R.H., Jr., 1979, An assessment of gas dissolved in sand-bed reservoirs in southern Louisiana and adjacent continental shelf; submitted as a part of the Report to Supply-Technical Advisory Task Force--Nonconventional Natural Gas Resources by sub-Task Force I: Gas Dissolved in Water; Gas Policy Advisory Council, Federal Energy Regulatory Commission, U.S. Department of Energy, Washington D.C., DOE/FERC-0029, p. 5-50, 46 p.

Wallace, R.H. Jr., Kraemer, T.F., Taylor, R.E., and Wesselman, J.B., 1979, Assessment of Geopressured-Geothermal Resources in the Northern Gulf of Mexico Basin: in Assessment of Geothermal Resources of the United States - 1978: U.S. Geol. Survey Circular 790, p. 132-155, 24 p.

SR056 Appalachian Basin - Waste Storage

PROJECT TITLE: Deformational response of the southern half of the Appalachian Basin to tectonic stresses - a major controlling factor in determining structure-related distribution of porosity and permeability trends that control waste-storage potential in the subsurface

WRD PROJECT NO.: SR 77-056

LOCATION: Southern Appalachian Basin

PROJECT CHIEF: Brown, Philip M.

HEADQUARTERS OFFICE: Raleigh, NC

PROBLEM: To assess the physical potential for deep-well waste disposal in the southern half of the Appalachian Basin, a region of geohydrologic complexity.

OBJECTIVE: To determine the presence, thickness, lateral extent and composition of rocks that have potential, as reservoirs and reservoir seals, for the emplacement and storage of liquid waste in the deep subsurface segments of the Appalachian Basin by means of tectonic-structural-stratigraphic analysis.

APPROACH: Analyze subsurface data obtained from previously drilled wells. Couple the analyses with an integration of areal tectonics, structure and stratigraphy as they pertain to the location, manner of emplacement, and composition of depositional environments that have potential for waste storage. The approach will combine the techniques and methods stated in Prof. Papers 796 and 881.

PROGRESS AND RESULTS: Collection of basin-wide geologic and geophysical data from subsurface completed. Basin-wide correlation of chronostratigraphic units established. Regional structural patterns established and partially field checked. Basin-wide lineament and fracture analysis using aerial photos **+(-) 40 percent complete. Analysis of borehole geologic data **+(-) 90 percent complete. Analysis of borehole geophysical data **+(-) 30 percent complete. Map posting of deterministic waste-storage parameters **+(-) 20 percent complete.

WD013 Limestone Hydraulic Permeabilty

PROJECT TITLE: HYDRAULIC PERMEABILITY OF LIMESTONE AQUIFERS IN THE UNITED STATES

WRD PROJECT NO.: WD 68-013

LOCATION: tropical research

PROJECT CHIEF: STRINGFIELD, VICTOR T.

HEADQUARTERS OFFICE: WASHINGTON, DC

PROBLEM: SOME LIMESTONE FORMATIONS, SUCH AS THE PRINCIPAL ARTESIAN IN FLORIDA AND GEORGIA AND THE SHALLOW AQUIFER (BISCAYNE) IN SOUTHEASTERN FLORIDA ARE AMONG THE MOST PRODUCTIVE AQUIFERS IN THE UNITED STATES. OTHER CARBONATE AQUIFERS AS THE SELMA CHALK IN ALABAMA AND THE COOPER MARL IN SOUTH CAROLINA YIELD LITTLE OR NO WATER. THE URGENT PROBLEM IS TO DETERMINE HOW, WHEN AND WHERE PERMEABILITY DEVELOPS IN SOLUBLE ROCKS IN ORDER TO PREDICT WHERE THE PRODUCTIVE PARTS OF THE AQUIFERS OCCUR. THE INFORMATION IS REQUIRED IN ORDER TO MAKE RELIABLE ESTIMATES OF THE WATER RESOURCES OF LIMESTONE REGIONS.

OBJECTIVE: CONTINUE STUDIES OF THE HYDROGEOLOGY OF CARBONATE TERRANES INCLUDING ARTESIAN SYSTEMS IN CARBONATE ROCKS TO DETERMINE HOW, WHEN AND WHERE PERMEABILITY IS FORMED IN CARBONATE ROCKS. ALTHOUGH THE PRIMARY PERMEABILITY MAY BE SIGNIFICANT, SECONDARY PERMEABILITY RESULTING FROM DISSOLUTION OF THE ROCKS ACCOUNTS FOR THE LARGE WATER YEILD FROM THE MOST PRODUCTIVE AQUIFERS. THE PROJECT IS DESIGNED TO AID NOT ONLY IN UNDERSTANDING AND PREDICTING PERMEABILITY DISTRIBUTION BUT ALSO PRINCIPLES OF OCCURRENCE AND MOVEMENT OF WATER, AND THE EFFECTS OF KARSTIFICATION ON TOPOGRAPHY AND SURFACE STREAMS IN REGIONS WHERE CARBONATE ROCKS ARE AT OR NEAR THE SURFACE. THE RESULTS OF THE STUDY WILL AID NOT ONLY IN PROBLEMS OF WATER SUPPLY BUT ALSO ENVIRONMENTAL PROBLEMS SUCH AS NEW SINKHOLES AND POLLUTION OF WATER SUPPLIES.

APPROACH: THE STUDIES ARE BASED CHIEFLY ON INFORMATION OBTAINED IN THE PAST AND ON CURRENT INVESTIGATIONS. THE LITERATURE IS EXAMINED AND USED AS IT BECOMES AVAILABLE. FROM TIME TO TIME CARBONATE AREAS WERE EXAMINED IN THE FIELD TO OBTAIN NEW INFORMATION AND TO CHECK TENTATIVE CONCLUSIONS. THESE AREAS INCLUDED (1) CARBONATE ROCKS ON THE EAST FLANK OF THE BLACK HILLS IN SOUTH DAKOTA, (2) EDWARDS LIMESTONE AQUIFER IN THE SAN ANTONIO AREA, TEXAS, (3) TERTIARY CARBONATE AQUIFERS IN CENTRAL FLORIDA, (4) THE CAMP BRANCH ANTICLINE IN SHELBY COUNTY, ALABAMA, AND (5) SOUTHERN INDIANA.

PROGRESS AND RESULTS: THE MOST PRODUCTIVE CARBONATE AQUIFERS IN THE U S ARE THOSE IN WHICH THE PERMEABILITY IN PALEOKARST HAS BEEN REACTIVATED BY THE PRESENT CIRCULATION SYSTEM. STUDIES MADE THUS FAR SHOW THAT THE PERMEABILITY OF PRODUCTIVE CARBONATE AQUIFERS IS CHIEFLY SECONDARY DUE TO DISSOLUTION OF THE CARBONATE ROCKS. THE EXTENT TO WHICH DISSOLUTION TAKES PLACE DEPENDS TO A LARGE EXTENT ON 1) THE CONDITIONS UNDER WHICH METEORIC WATER ENTERS THE ROCKS, 2) THE CIRCULATION SYSTEM IN THE ZONE OF SATURATION, 3) RELATION OF GEOLOGIC STRUCTURE TO THE CIRCULATION SYSTEM, 4) CHANGES IN LOCAL BASE LEVEL,

AND 5) PRESENCE OR ABSENCE OF BURIED PALEOKARST. SOME OF THE RESULTS OF THESE STUDIES ARE GIVEN IN TECHNICAL REPORTS LISTED BELOW FOR 1974.

WD115 Groundwater Geophysics Research

PROJECT TITLE: Development of Surface Geophysical Methods for Application to Problems in Ground Water Hydrology

WRD PROJECT NO.: WD 76-115

LOCATION: Topical

PROJECT CHIEF: Zohdy, Adel A. R.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Common to all hydrologic investigation of ground water systems is the requirement of defining the geologic nature and hydraulic properties of the media that store and transmit ground water. The primary characteristics of the media, such as lithology, porosity and permeability are commonly obtained from laboratory analysis of samples obtained from wells. Such measurements are expensive, and generally are far too few to describe the regional character and variability of the geologic strata that control the movement of ground water. Surface geophysical methods offer a means of measuring secondary characteristics of the media, such as the conduction of electrical or mechanical energy, and inferring from such data the regional extent, thickness, structure and lithology of the underlying rocks.

OBJECTIVE: (1) To apply and extend theory underlying the use of a variety of surface geophysical techniques, and to develop new theoretical models and interpretative techniques. (2) To test and demonstrate the effectiveness of these new techniques in practical field applications. (3) To instruct selected WRD personnel in the theory, use and limitations of the new techniques.

APPROACH: About 80 percent of this effort will be spent in the development and testing of mathematical and physical models. The use of such models will extend the use of resistivity and other data to two- and three-dimensional problems. Tank models will be used to establish interpretative procedures based on "total field" measurements, and computer programs will be developed for automatic processing of data. About 20 percent of the project time will be spent in the field testing new techniques.

WR078 Hyd Sub Waste Disp-Inel, Idaho

PROJECT TITLE: Hydrology of Subsurface Waste Disposal, Idaho National Engineering Laboratory, Idaho

WRD PROJECT NO.: WR 60-078

LOCATION: Southeastern Idaho

PROJECT CHIEF: BARRACLOUGH, JACK T.

HEADQUARTERS OFFICE: IDAHO FALLS, ID

PROBLEM: The Idaho National Engineering Laboratory obtains its water supply from the Snake River Plain aquifer and disposes low-level radioactive and chemical wastes to the environment. Solid radioactive wastes have been buried in this area in the past. Because of increased concern about water pollution problems, detailed knowledge is needed about the geochemical, hydrological, and geological influences of this major energy development center on the ground-water resources of the area. Information is needed on deeper zones of the Snake River Plain aquifer to determine if wastes may move downward or could be stored at depth.

OBJECTIVE: Describe, evaluate, and assess the effects of radioactive and chemical waste disposal at the Idaho National Engineering Laboratory on the ground-water resources, contribute to the technology of waste disposal, and study manner of water and solute movement in fractured rocks. Map and describe distribution patterns of waste products in the ground water so predictions of future patterns can be made. Evaluate the hydrogeochemical controls on the subsurface migration of solutions from bodies of buried solid radioactive waste. Evaluate the hydrologic properties of deeper zones in the Snake River Plain.

APPROACH: The study of the subsurface effects of waste disposal upon the Snake River Plain aquifer compares the current conditions with previous data. Distribution and dispersion patterns, rates of movement, dilution factors, and mass balances of various components will be evaluated and compared for several time periods. Radiochemical, geochemical, and hydraulic processes affecting the changes will be evaluated. Hydraulic dispersion, radioactive decay, and sorption phenomena will be studied using digital models. Permeable and impermeable zones at depth will be determined and mapped.

PROGRESS AND RESULTS: Studied distribution and migration of organic compounds and plutonium in the Snake River Plain aquifer. Participated in Department of Energy (DOE) program of drilling 8 wells to monitor waste plumes in the aquifer. Began updating digital models to provide better waste-prediction capability. Developed remote stations using windmills, pressure transducers, and pumps at an isolated radioactive-waste facility. Upgraded Project geophysical-logging capability. Provided consultation to DOE in a variety of geohydrologic topics. Made presentations related to subsurface waste disposal in the region of the Snake River Plain aquifer before a congressional hearing, a State task force and several

citizens' groups.

COMPLETED REPORTS:

Barraclough, J.T., Geohydrology of the Eastern Snake River Plain, Idaho, as shown by a 2-mile-deep well (Abstract), Amer. Geophysical Union, Pacific Northwest Regional Meeting, September 1979.

Druffel, Leroy, Stiltner, Gloria J., and Keefer, Thomas N., Probable Hydrologic Effects of a Hypothetical Failure of Mackay Dam on the Big Lost River Valley from Mackay, Idaho, to the Idaho National Engineering Laboratory, U.S. Geol. Survey, WRI-79-99, Issued by DOE as IDO-22058.

WR082 Geothermal Hydrologic Reconnaissance

PROJECT TITLE: Hydrologic reconnaissance of geothermal areas in Nevada and California

WRD PROJECT NO.: WR 72-082

LOCATION: STATES OF CALIFORNIA AND NEVADA

PROJECT CHIEF: OLMSTED, FRANKLIN H.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Geothermal energy is receiving attention as a source for the development of electricity and for various nonelectrical uses. Optimum development of the resource must be preceded by a rational program of exploration and evaluation. Improved understanding is needed of conditions that control the occurrence of hydrothermal convection systems in the Basin and Range physiographic province of the western United States. Such understanding will greatly facilitate evaluation of known systems and prediction of the occurrence of hitherto unknown systems.

OBJECTIVE: (1) Describe the hydrologic environment of four geothermal areas in northern and central Nevada; (2) Determine the most probable recharge areas and ground-water flow paths; (3) Interpret geologic, goechemical, geophysical, thermal, and hydrodynamic information in terms of the configuration of each hydrothermal reservoir and its hydrologic properties; (4) Provide the basis for analytical or numerical-modeling studies of each reservoir and associated hydrothermal flow system; and (5) Evaluate the utility of delineating prospective geothermal areas.

APPROACH: (1) REVIEW LITERATURE AND CANVASS PUBLIC AGENCIES AND PRIVATE COMPANIES FOR AVAILABLE HYDROLOGIC DATA. CATALOG AVAILABLE DATA AND PREPARE A TABULAR SUMMARY OF DEFICIENCIES. (2) IN COLLABORATION WITH GEOLOGISTS AND GEOCHEMISTS WHO WILL BE MAKING COMPANION STUDIES, SELECT GEOTHERMAL AREAS TO BE STUDIED. (3) INVENTORY WELLS AND SPRINGS, MEASURE THE DISCHARGE OF FLOWING WELLS AND SPRINGS AND OF STREAMS INTO WHICH THESE DRAIN. COMPILE PRECIPITATION AND RUNOFF DATA PERTINENT TO ASCENTAINING AREAS AND MAGNITUDE OF RECHARGE. COMPILATION OF GEOLOGIC DATA MAY BE REQUIRED WHERE THE RECHARGE AREA FOR A SYSTEM IS INFERRED TO BE FAR FROM THE DISCHARGE AREA. (4) ASSIST IN SAMPLING WATER SOURCES FOR CHEMICAL ANALYSIS. SAMPLE SELECTED WELLS AND SPRINGS FOR CARBON, OXYGEN, AND HYDROGEN ISOTOPES WHERE REQUIRED FOR HYDROLOGIC ANALYSIS. (5) DESIGN AND CARRY OUT A PROGRAM OF SHALLOW TEST DRILLING FOR SUPPLEMENTARY DATA. (6) PREPARE GEOHYDROLOGIC MAPS AND CROSS SECTIONS OF SEVERAL KINDS FROM INFORMATION GATHERED IN ACTIVITIES (3), (4), AND (5) LISTED ABOVE. (7) IN COLLABORATION WITH PERSONNEL OF GEOLOGIC AND WATER RESOURCES DIVISIONS, USING RESULTS OF GEOLOGIC, GEOCHEMICAL, GEOPHYSICAL, THERMAL, AND HYDRODYNAMIC STUDIES, DEVELOP CONCEPTUAL MODELS OF THE FLOW SYSTEMS.

PROGRESS AND RESULTS: Final paper on hydrogeologic appraisal of Beowave Geysers hydrothermal system was begun. Completed field work

and numerical modeling of hydrothermal system in southern Grass Valley, and nearly completed paper on that system. Completed revision of paper on Stillwater hydrothermal system. Continued water-level and soil-temperature measurements in western Carson Desert. Paper on Pallmann (sugar-solution) method of soil-temperature integration as applied to geothermal areas in western Carson Desert awaiting publication.

WR108 GEOTHERMAL COORDINATION-OLMSTEAD

PROJECT TITLE: TECHNICAL COORDINATION AND SUPPORT OF WRD GEOTHERMAL STUDIES

WRD PROJECT NO.: WR 00-108

LOCATION: MENLO PARK, CALIFORNIA

PROJECT CHIEF: Olmsted, Franklin H.

HEADQUARTERS OFFICE: MENLO PARK, CA

PROBLEM: GEOTHERMAL STUDIES IN THE WATER RESOURCES DIVISION ARE PART OF A NATIONWIDE RESEARCH AND MAPPING PROGRAM OF THE GEOLOGICAL SURVEY, FUNDED AS A LINE ITEM IN THE GEOLOGIC DIVISION BUDGET. THESE STUDIES REQUIRE PLANNING, COORDINATION, TECHNICAL SURVEILLANCE, AND LOGISTICAL SUPPORT.

OBJECTIVE: TO PROVIDE PLANNING, TECHNICAL SURVEILLANCE, COORDINATION AND LOGISTICAL SUPPORT SERVICES TO WRD GEOTHERMAL INVESTIGATIONS.

APPROACH: COORDINATOR PLANS, ARRANGES FOR STAFFING, APPROVES BUDGETS, MAINTAINS TECHNICAL SURVEILLANCE AND ADVISES THE CHIEF HYDROLOGIST THROUGH APPROPRIATE STAFF ON THE GEOTHERMAL PROGRAM. REVIEWS NEEDS FOR TEST DRILLING AND OTHER LOGISTICAL SUPPORT AS WORK PROGRESSES AND MAKES NECESSARY SUPPORT FUNDS AVAILABLE.

PROGRESS AND RESULTS: The WRD Geothermal Studies Coordinator continued his activities of coordinating geothermal research in WRD with that of other divisions in the Geological Survey and with that of other Federal agencies. The WRD research projects, treating principles, processes, and specific geothermal systems, were continued over a wide range of subject areas and in diverse geographic areas. Support was given to several projects, funded in part under geothermal program, for purchase of equipment and other miscellaneous activities.

WR121 Geothermal Reconnaissance Oregon

PROJECT TITLE: Reconnaissance studies and numerical modeling of geothermal areas in Oregon

WRD PROJECT NO.: WR 74-121

LOCATION: OREGON STATEWIDE

PROJECT CHIEF: SAMMEL, EDWARD A.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: THE NEED FOR INCREASED DEVELOPMENT OF GEOTHERMAL RESOURCES FOR ELECTRICAL ENERGY, FRESH WATER, AND MINERALS HAS BEEN WELL ESTABLISHED. THE GEOLOGICAL SURVEY HAS ASSUMED MUCH OF THE RESPONSIBILITY FOR MAKING RECONNAISSANCE SURVEYS AS A FIRST STEP IN THE EXPLORATION AND EVALUATION OF KNOWN GEOTHERMAL RESOURCE AREAS. SEVEN OF THE KNOWN GEOTHERMAL RESOURCE AREAS IN THE U S ARE IN OREGON, ALTHOUGH THE MAGNITUDES OF THESE RESOURCES ARE ESSENTIALLY UNKNOWN. IN ORDER TO EVALUATE THE MOST PROMISING AREAS, IT WILL BE NECESSARY TO RELATE THE CONCURRENT GEOLOGIC, GEOCHEMICAL, AND GEOPHYSICAL STUDIES TO THE PROPOSED HYDROLOGIC RECONNAISSANCE AND THUS PROVIDE A BASIS FOR MORE DETAILED FUTURE STUDIES.

OBJECTIVE: THE OBJECTIVES OF THE STUDY ARE TO (1) DESCRIBE THE HYDROLOGIC ENVIRONMENT OF SEVERAL IDENTIFIED BUT UNEVALUATED GEOTHERMAL RESERVOIRS IN OREGON, (2) ASCERTAIN PROBABLE RECHARGE AND DISCHARGE AREAS, (3) DETERMINE MODES AND QUANTITIES OF RECHARGE AND DISCHARGE, (4) INTERPRET GEOLOGIC, GEOCHEMICAL, GEOPHYSICAL, AND HYDRODYNAMIC DATA IN TERMS OF THE SIZE, SHAPE, AND HYDRAULIC CHARACTERISTICS OF THE RESERVOIRS, AND (5) PROVIDE A BASIS FOR A LONG-TERM DETAILED QUANTITATIVE APPRAISAL OF EACH RESERVOIR.

APPROACH: (1) IN COLLABORATION WITH GEOLOGISTS, GEOCHEMISTS, AND GEOPHYSICISTS WHO ARE MAKING CONCURRENT STUDIES, SELECT SPECIFIC AREAS TO BE STUDIED. (2) COLLECT AND TABULATE AVAILABLE HYDROLOGIC DATA FROM THE LITERATURE AND FROM THE FILES OF PUBLIC AND PRIVATE AGENCIES. (3) WHERE DATA ARE DEFICIENT, SUPPLEMENT BY FIELD INVENTORY, MEASUREMENT, AND SAMPLING. (4) DESIGN AND CARRY OUT PROGRAM OF TEST DRILLING, AQUIFER TESTING, AND BOREHOLE GEOPHYSICS. (5) PREPARE GEOHYDROLOGIC MAPS AND CROSS SECTIONS FOR DISPLAY AND EVALUATION OF DATA. IN COLLABORATION WITH COLLEAGUES IN RELATED DISCIPLINED DEVELOP SEMI-QUANTITATIVE CONCEPTUAL MODELS OF THE FLOW SYSTEM. (6) Construct numerical models of heat and mass flow for selected systems in order to quantify the potential for development.

PROGRESS AND RESULTS: Drilling of test hole for geologic and hydrologic information stopped at 2070 feet because of adverse weather; the information obtained is of great interest to geologists and geophysicists. Analysis of data from Warner Valley indicates a moderately high-temperature (perspective to 170 degrees C) geothermal system that is fault-controlled and possibly restricted to major fault zones and shallow spreading zones. Preliminary numerical models of Klamath Falls geothermal system will be useful as basis for future convective models.

COMPLETED REPORTS:

Sammel, E.A., 1979, Occurrence of Low-Temperature Geothermal Waters in the United States, in Muffler, L.J.P., ed., Assessment of Geothermal Resources of the United States--1978: U.S. Geological Survey Circular 790, p. 86-131

Sammel, Edward A., 1980, Hydrogeologic appraisal of the Klamath Falls geothermal area, Oregon: U.S. Geol. Survey Prof. Paper 1044-G, 45 p.

Muffler, L.J.P., Costain, J.K. Foley, Duncan, Sammel, E.A., and Youngquist, Walter, 1980, Nature and distribution of geothermal energy; in Anderson, D.N., and Lund, J.W., eds., Direct utilization of geothermal energy: a technical handbook: Geothermal Resources Council Special Report No. 7, p. 1.1 - 1.15, 15 p.

WR129 Intermediate Depth Drilling

PROJECT TITLE: INTERMEDIATE DEPTH DRILLING AND TESTING OF HYDROTHERMAL SYSTEMS

WRD PROJECT NO.: WR 75-129

LOCATION: Selected Sites - CA, NV, OR, ID

PROJECT CHIEF: DUTCHER, LEE C.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: TECHNIQUES NECESSARY FOR LOCATING GEOTHERMAL RESOURCES OF ALL TYPES AND FOR ESTIMATING THEIR INDIVIDUAL SIZE AND ENERGY POTENTIAL ARE NOT WELL DEVELOPED; IN MANY GEOTHERMAL AREAS DATA ARE NOT AVAILABLE ON WHICH TO BASE ESTIMATES OF HEAT FLOW; ALSO LACKING ARE DATA ON THE GEOLOGIC STRUCTURE, LOCATION AND CHARACTER OF AQUIFERS, PRESSURE AND TEMPERATURE GRADIENTS AND WATER QUALITY.

OBJECTIVE: DRILL AND TEST WELLS TO PROVIDE GEOLOGIC, HYDROLOGIC, WATER-QUALITY AND HEAT-FLOW DATA NEEDED FOR FORMULATING CONCEPTUAL MODELS OF GEOTHERMAL SYSTEMS AND FOR ESTIMATING THEIR SIZE AND ENERGY POTENTIAL. TECHNIQUES MUST BE DEVELOPED FOR COLLECTING BOTH HYDROLOGIC AND HEAT-FLOW INFORMATION FROM A SINGLE HOLE, WHEREVER POSSIBLE.

APPROACH: MEMORANDUM OF UNDERSTANDING WITH BUREAU OF RECLAMATION CONCERNING THEIR RIG AND CREW WILL PROVIDE AN INTERMEDIATE-DEPTH DRILLING CAPABILITY ON VIRTUALLY A YEAR-AROUND BASIS WHICH CAN BE USED IN SUPPORT OF HYDROLOGIC INVESTIGATIONS OF GEOTHERMAL SYSTEMS THROUGHOUT THE WESTERN UNITED STATES. USGS WILL SUPPLY THE CEMENT, DRILLING MUD, PIPE, CASING, AND ASSOCIATED INCIDENTALS USED IN SUPPORT OF THE DRILLING OPERATIONS.

PROGRESS AND RESULTS: The wells in the Black Rock Desert and Ennis Montana, were completed as planned. The core drilling at Newberry Crater, Oregon, was suspended due to weather. The depth reached was 2002 ft and a request was made to continue in 1980 on the 1979 contract. I assisted on a special project at Mt. Hood, Oregon; one well was completed to 2000 ft, two to 1200 ft and a fourth well was discontinued due to weather. On a new contract for Nevada, two wells were completed near Fallon 1000 ft and 130 ft. Plans and specifications have been submitted to drill 4 new wells 800-1800 ft on Mt. Hood and to deepen the 2000 ft well to 4000 ft. We have purchased casing and material to be used by the Denver based drilling rig. We plan to drill 15 new holes to a depth of 100-150 meters in the Black Rock Desert of Nevada on a contract already in force as soon as weather permits. The Newberry Crater well will be drilled to 500 ft. The project is due to be terminated at the end of FY 80. Item (24) will consist of a statement of drilling work (now in progress) completed, and submission of a report now would introduce incomplete information into MIS.

WR159 Geothermal, Coachella Valley

PROJECT TITLE: Geothermal hydrology of lower Coachella Valley, southeastern California

WRD PROJECT NO.: WR 78-159

LOCATION: Southeastern California

PROJECT CHIEF: Robison, James H.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Coachella Valley is formed and bounded by faults of the San Andreas system. The valley is part of the Salton Trough, within which are several promising geothermal fields of Imperial Valley, and a producing geothermal field at Cerro Prieto, Mexico. To date there has been little serious geothermal exploration or assessment in the Coachella area. There are hints of possible high heat flow in Coachella Valley; these include areas of warm or hot springs, and higher than expected temperatures have been reported for some flowing water wells at the lower end of the valley.

OBJECTIVE: The objectives of the proposed study are to: (1) describe the general geohydrologic framework of the Coachella Valley, especially as it may relate to any geothermal systems in the area; (2) evaluate geologic, geochemical, and geophysical data that may indicate geothermal potential of the area; and (2) outline any additional work that may be warranted for areas that appear to have high geothermal potential.

APPROACH: The following approach is suggested: (1) Collect and tabulate geologic and hydrologic data from the literature and from public and private agencies; (2) Make field measurements and inventories, and obtain samples for analysis where data are deficient; (3) Design and carry out a program of drilling and testing, for the purpose of obtaining temperature gradients, heat flow information, and water-quality data; (4) Calculate heat flow, using data obtained during the study; and (5) Evaluate conceptual models of the ground-water flow system that are consistent with hydraulic and geothermal data obtained during the study.

PROGRESS AND RESULTS: A drilling program of temperature-gradient holes and piezometers at 11 sites near Oasis, Calif., was completed. Drillers', geophysical, and temperature logs have been made of the wells, which average 150 m deep, have maximum temperatures to 47 degrees C, and gradients to 107 degrees C/km. Water samples from 8 piezometers have been analyzed. Owing to cutback in funds and diversion of project chief to other activities, the only work done on project in FY 1980 was continuation of scouting trips to Imperial Valley by William Hardt of Laguna Niguel Subdistrict Office to report on geothermal activity there.

WR171 Hydrologic Analysis of Petrofabrics

PROJECT TITLE: Hydrologic Analysis of Petrofabrics--Sandstones

WRD PROJECT NO.: WR 76-171

LOCATION: topical research

PROJECT CHIEF: Getzen, Rufus T.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Techniques for analyzing ground-water flow and for predicting the response of ground-water systems to natural and man-made stresses require quantitative descriptions of spatial variation in permeability. New techniques for three-dimensional simulation of ground-water flow and solute transport require detailed quantitative descriptions of dispersion characteristics and the permeability tensor that are difficult and expensive to obtain with current measurement techniques.

OBJECTIVE: (1) To determine the geologic factors affecting ground-water flow and the transport of heat and solutes in porous media; (2) to develop methods for estimating the relative importance of these geologic factors in various geologic settings and under various stress conditions; (3) to develop simple and inexpensive methods for measuring the requisite geologic factors and for estimating the dispersion characteristics and permeability tensor from them.

APPROACH: Sand-body geometry and the permeability tensor within a sand-body are related to the fabric of the deposit; thus methods of petrofabric analysis are being developed and tested on field samples. Trend analysis, multivariate correlation and regression, and other statistical techniques are being used to relate sand-body geometry and permeability tensor to petrofabric. Sensitivity analyses, including digital simulation, will be used to determine the degree of accuracy for permeability and dispersion measurements required for adequate analyses under various conditions of stress and in various geologic settings.

PROGRESS AND RESULTS: (1) A report on spectral analysis of bedforms was completed. (2) Techniques were developed for sampling, preserving, and studying sedimentary structures in fluvial sands; sampling completed for Congaree point bar. (3) Instruments and methods for measuring medium-scale (about 1 to 5 cubic meters of sediment) hydrologic anisotropy are partly developed. (4) Reports completed on instrumentation for large-scale anisotropy measurements and on preserving sedimentary structures.

COMPLETED REPORTS:

Levey, R.A., Kjerfve, Bjorn, and Getzen, R.T., 1980, Comparison of bedform variance spectra within a meander bend during flood and average discharge Jour. Sed. Pet., v. 50, p. 149-155

WD054 Well-Strain Meters

PROJECT TITLE: Water Wells as Strain Meters

WRD PROJECT NO.: WD 75-054

LOCATION: topical research

PROJECT CHIEF: Bredehoeft, John D.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: Water wells commonly show earth-tide fluctuations. Often the magnitude of the tidal fluctuation in the well is 1 to 2 cm. This fluctuation is produced by a tidal dilatation, the sum of the normal strains, of approximately 1x10**-8. This indicates that the water well is as sensitive to strains of the crust as the strain seismometer. The problem with the water well is that other factors such as changes in barometric pressure, aquifer recharge, and pumping can also cause the water-level to fluctuate. Utilizing the well for crustal strain measurements requires that we separate the strain response, the signal, from the other effects, in the case noise. This requires careful experiments in areas where we know the crustal strain.

OBJECTIVE: To use water wells as crustal strain indicators.

APPROACH: At the present time the U.S. Geological Survey (USGS) has instrumented two sets of wells along the San Andreas fault in California, one in the Palmdale area and a second in Imperial Valley, for the express purpose of sensing crustal strains. The plans are to increase the network with improved instrumentation which utilizes satellite telemetering of the data in FY81. We also plan to instrument wells at several dam sites where the reservoir fluctuations are believed to induce earthquakes.

PROGRESS AND RESULTS: Five Data Collection Systems Including Satellite Telemetery (Dep's) have been acquired.

CR090 RELATION OF GROUND WATER TO LAKES

PROJECT TITLE: THE ROLE OF LAKES IN THE HYDROLOGIC SYSTEM WITH EMPHASIS ON THEIR RELATION TO GROUND WATER

WRD PROJECT NO.: CR 74-090

LOCATION: Topical Research

PROJECT CHIEF: WINTER, THOMAS C.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Deterioration of the recreational and aesthetic values of lakes, of primary economic and ecologic importance to much of the U.S., is becoming an increasingly serious problem. Expensive studies and ineffective treatment of "problem lakes" are often found to have little transfer value to other lake problems. Further, the studies to date have emphasized the chemical and biological aspects of limnology and have paid little attention to lake hydrology which, in many situations, is basic to the chemical flux problems affecting lake quality. Research on lake hydrology is urgently needed by limnologists and water managers concerned with lake management and restoration.

OBJECTIVE: The major objective of the problem of lake hydrology research is to gain understanding of the basic principles controlling the interaction of lakes and ground water, including associated chemical fluxes. The project will emphasize integration of theoretical and experiment field work. Although research emphasis is on ground water, the project will also include state-of-the-art studies of the atmospheric and surface water components of lake hydrology, as needed in the evaluation of the ground-water component. Evaluation of error in hydrologic methodology for the various aspects of lake water balances will be an integral part of the research effort.

APPROACH: The general approach of the lake hydrology studies will be to construct theoretical and field related mathematical models of steady-state and transient, variably-saturated ground-water conditions as related to lakes. Field experimental sites are being established in selected parts of the U.S. for calibration and modification of models, instruments and methodology. All components of the hydrologic system, as related to the experimental lakes, will be measured by various state-of-the-art methods in support of the ground-water studies. At selected sites chemical flux studies are being integrated with the hydrologic work. Information from the field sites will be used for evaluation of error in various approaches of determining lake water and chemical balances.

PROGRESS AND RESULTS: Work continued on modeling transient ground-water flow near lakes using a finite-element model that handles saturated and unsaturated conditions. Instrumentation of field sites for total water balance studies continued at Williams Lake(MN), Cottonwood Lake(ND), Mirror Lake(NH), Pine Lake(WA). Nutrient budget studies continued at Gross and Williams Fork Reservoir(CO) and were initiated at Williams Lake and Cottonwood Lake. Several papers were prepared and approved for publication on (1) the effect on budget

studies of errors in hydrologic measurement, (2) evaluation of phosphorus models as related to reservoir water quality, and (3) hydrologic setting of Williams Lake.

COMPLETED REPORTS:

Winter, T.C., 1978, Numerical simulation of steady-state, three-dimensional ground water flow near lakes: Water Resources Research, v. 14, no. 2, pp. 245-254.

Winter, T.C., 1979, Role of ground water in lake water balances: Proceedings of Lake Management Conference June 9, 1977, University of Connecticut Inst. of Water Resources, Report no. 30, p. 5-29, 24 p.

Siegel, D.I., and Winter, T.C., 1980, Hydrologic setting of Williams Lake, Hubbard County, Minnesota: U.S. Geol. Survey Open-File Report 80-403, 56 p.

Carr, M.R., and Winter, T.C., 1980, An annotated bibliography of devices developed for direct measurement of seepage: U.S. Geol. Survey Open-File Report 80-344, 38 p.

Winter, T.C., 1979, Role of ground water in lake water balances: Proceedings of Lake Management Conf. June 9, 1977, Univ. of Connecticut, Inst. of Water Resources Report no. 30, p. 5-29, 25 p.

CR191 Simulation of Hydrogeologic Systems

PROJECT TITLE: Mathematical Simulation of Hydrogeologic Systems

WRD PROJECT NO.: CR 76-191

LOCATION: TOPICAL RESEARCH

PROJECT CHIEF: Cooley, Richard L.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Satisfactory formulations and solutions of equations approximately describing (1) movement of fluids and components contained in fluids through consolidated and unconsolidated rocks, and (2) interactions of the fluids and rocks accompanying fluid movement, are needed for proper understanding and management of ground-water resources. Such formulations and solutions of equations that apply for general field situations where the flow system is complex and hydrologic data are inexact are not, in general, available.

OBJECTIVE: Evaluate presently used equations and, where necessary, (1) formulate new approximate equations pertaining to flow of fluids through porous or fractured rock emphasizing equations that are tractable for field use, (2) apply and (or) compare the best techniques available, or derive new ones, to solve the equations, (3) derive efficient techniques for estimations of parameters contained in the equations, (4) assess the degree of reliability and significance of both the model formed by the basic equations and the parameters estimated for it in terms of the imput data, and (5) assess the degree of reliability and predicitive capability of the model.

APPROACH: The fundamental equations are developed utilizing the methods of mathematical physics together with basic physical concepts from geology, geochemistry, geophysics, etc. Solutions to the equations are to be developed analytically and (or) numerically, depending on the problem. Analysis of error propagation, stability, and convergence using techniques of linear and nonlinear algebra will accompany numerical solution procedures where feasible and appropriate. Parameter calculation is to be approached through techniques of nonlinear regression so that the reliability and significance of estimated parameters and the predictive capability of the model can be assessed.

PROGRESS AND RESULTS: Development continued of techniques for the nonlinear regression solution of steady-state ground-water flow problems. For these methods, the dependent variable is hydraulic head, and parameters are the various values of transmissivity or hydraulic conductivity, recharge-discharge, vertical hydraulic conductivity of confining beds, specified fluxes across boundaries, and specified heads on boundaries. Sensitivities are calculated numerically using a numerical flow model. Completed work includes: (1) A method of utilizing biased, prior information in the form of order-of-magnitude prior estimates of parameters (2) A new finite difference version of the nonlinear regression program that incorporates the new biased-estimation method. (3) Theoretical work on a method of

computing nonlinear confidence regions for the estimated parameters. A paper and the numerical experiments for a second paper have been completed for item (1) and papers are underway or planned for items (2) and (3). A technique was derived for solution of unsaturated flow equations. The technique, which is a hybrid of quasilinearization, gradient search and SIP factorization methods, is currently being evaluated, but appears to be very promising. Initial work was completed on a stochastic model to estimate recharge in natural environments. The model assumes that precipitation and water-level fluctations are stochastic random variables. Aquifer responses are estimated with a Dupuit model. The unsaturated zoned is approximated with a delay function.

COMPLETED REPORTS:

Cooley, R.L., A method of estimating parameters and assessing reliability for models of steady-state ground water flow 2. Application of statistical analysis: Water Resources Research, v. 15, no. 3, pp. 603-617, 14 p.

CR211 NTS Hydrologic Model

PROJECT TITLE: Modeling of Ground-water Flow and Solute Transport at Nevada Test Site

WRD PROJECT NO.: CR 77-211

LOCATION: South-central Nevada

PROJECT CHIEF: Waddell, Richard K.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: In the past 25 year more than 350 underground nuclear explosions have emplaced large amounts of radioactive materials beneath the land surface. About 25 percent of the tests were conducted beneath the water table. The presence of these materials and the possibility of future storage of nuclear fuel wastes at NTS makes it mandatory that we know the paths of movement of contaminated ground water and the physico-chemical changes taking place. A mathematical model of this system is needed to enable prediction of radionuclide concentration spatially and temporally for the purpose of public safety and future planning.

OBJECTIVE: To take existing test-hole, hydraulic and geologic data and model the local, intermediate and regional groundwater flow pattern if possible. Once the basic flow patterns have been modeled a solute transport model will be superimposed to predict the concentrations of radionuclides in the aquifer as functions of time, space and travel distance. Attempts will be made to determine the amount of sorption and dispersion of these nuclides along the flow paths. Ultimately a map of underground contamination will be completed which can be used to determine the most advantageous area in which to dispose of radioactive wastes, and to predict their behavior and movement with time.

APPROACH: (1) Review and catalog all surface and subsurface geologic, hydrologic, and chemical data applicable to the study; (2) Produce a two-dimensional flow model for regional flow and perform sensitivity analyses; and (3) Perform model tranport of radionuclides from a hypothetical high-level nuclear waste repository in two and three dimensions.

PROGRESS AND RESULTS: Hydrologic data have been compiled. Two-dimensional modeling of flow has been performed using parameter estimating techniques. Sensitivity analysis of the flow modeling has been begun using Monte Carlo-regression techniques to determine types of data most pertinent to the modeling effort.

CR233 Climax Heater Experiment

PROJECT TITLE: Effects of high thermal stresses on pore-fluid pressures and permeability in rocks

WRD PROJECT NO.: CR 78-233

LOCATION: Nevada Test Site, Nevada

PROJECT CHIEF: Waddell, Richard K.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: The heat from high-level radioactive wastes is expected to produce significant increases of fluid pressure in rock interstices. Geochemical reactions in the induced hydrothermal environment may either increase or reduce both the permeability to fluids and thermal conductivity. In some rocks, pore-fluid pressures may be increased sufficiently to hydrofrac the rock, greatly increasing the permeability and the availability of additional water to the waste.

OBJECTIVE: (1) Develop an understanding of the influence of water content, initial rock permeability, bulk thermal properties, time, and distance from the heat source on in-situ (confined) pore-fluid pressure and subsequent permeability.

APPROACH: Hydrologic holes, drilled near heater emplacement holes, were equipped with instrumentation to monitor temperature and pressure in a confined portion of the hole. These measurements were conducted during several phases of heating as functions of time, and recorded on tape for processing. Data will be analyzed to determine the effects of steam production on fluid pressures, and to determine the effect of heating on permeability.

PROGRESS AND RESULTS: Temperature and pressure were monitored in a borehole located 0.5 m. from an electrical heater with a maximum output of 4.8 KW. Pressure appears to have been controlled by non-ideal gas law in the single-phase region, and by the water-steam phase boundary in the 2-phase region.

CR256 MECHANICS OF AQUIFER SYSTEM

PROJECT TITLE: Mechanics of Aquifer Systems - Field Research

WRD PROJECT NO.: CR 76-256

LOCATION: Western and Central U S

PROJECT CHIEF: Riley, Francis S.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Land subsidence due to ground-water overdraft significantly affects possibly 10,000 square miles, principally in five states. Surface fissuring and faulting are associated with the subsidence in several important areas. Costly engineering and environmental problems frequently result from these kinds of deformation. Monitoring of the vertical and horizontal deformations of aquifer systems resulting from observed changes in hydraulic stress allows the affected areas to serve as field laboratories for studying hydrogeologic processes. Basic hydraulic, mechanical, and geologic parameters of aquifer systems can be devired from such studies and can be used to model the systems' behavior.

OBJECTIVE: This project seeks to determine or refine the principles controlling vertical and horizontal deformation of aquifer systems resulting from changes in effective stress; to evaluate hydraulic and mechanical parameters of aquifer systems by analyzing measured deformation in response to measured stress changes in both the recoverable and nonrecoverable ranges of deformation; to test and enhance the applicability of laboratory tests (including new procedures developed in the project) in estimating aquifer-system deformation and the resulting subsidence and failures at land surface.

APPROACH: Precisely monitor vertical and horizontal ground-water movement and associated changes in pore pressure, and measure subsurface vertical and horizontal deformation within stressed aquifer systems, through application of existing and newly developed instrumentation; perform laboratory tests on cores from sites where field measurements have yielded in situ values of aquifer-system parameters and, if necessary, develop improved equipment and techniques for such tests; expand existing and develop new conceptual, analytical, and numerical models to account for skeletal deformation due to changes in pore pressures; test the predictive capabilities of such models against the historical data from field monitoring sites and against laboratory data; serve as consultant on subsidence problems in numerous areas.

PROGRESS AND RESULTS: Analysis of repeated measurements of horizontal deformation in areas of subsidence and earth fissuring in central Arizona show continuing localized strain rates in excess of 4x10**-4/year. Refinements in the tape extensometer technique used for many of these measurements have resulted in data sets having a standard deviation of about 5 ppm. The data reveal substantial spatial inhomogenieties and temporal variation in strain, suggestive of complex boundary conditions on the 3-dimensional deformation process.

Attempts to model the 2-dimensional strain data with a uniform horizontal strain-field solution met with only limited success. An intensive local gravity net has been established to augment existing data on the configuration of the highly irregular bedrock surface underlying the deforming aquifer system. Five new arrays of horizontal and vertical control stations have been measured at sites of known or potential fissuring, and recording long-base (30 meters) horizontal strain meters are being installed at two of these sites. A bore-hole (vertical) extensometer is also scheduled for installation at one of these sites before the end of FY 80. Five previously established EDM (electronic distance measurement) lines were resurveyed. Establishment of a computerized data base and data reduction system is in progress.

COMPLETED REPORTS:

Holzer, T.L., Davis, S.N., and Lofgren, B.E., 1979, Faulting caused by ground-water extraction in south-central Arizona: Journal of Geophysical Research, v. 84, no. B2, p. 603-612, 10 p.

Lofgren, B.E., 1979, Changes in aquifer-system properties with ground-water depletion: Evaluation and prediction of subsidence, Pensacola Beach, FL, 1978, ASCE, p. 26-36, 11 p.

Poland, J.F., Subsidence due to ground-water withdrawal, a summary for United States, ASCE Nat'l Meeting, Oct. 1979, 1 p.

Raymond, R.H., Laney, R.L., Pankratz, L.W., Riley, F.S., Carpenter, M.C., Relationship of earth fissures in alluvial basins in south-central Arizona to irregularities in the underlying formations, 1 p.

CR257 GEOTHERMAL SUBSIDENCE RESEARCH

PROJECT TITLE: SUBSIDENCE AND RELATED ASPECTS OF GEOTHERMAL SYSTEMS

WRD PROJECT NO.: CR 72-257

LOCATION: IMPERIAL VALLEY AND GEYSERS AREAS, CALIFORNIA

PROJECT CHIEF: Riley, Francis S.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Subsidence and ground movement frequently accompany intensive withdrawal of formation fluids. These effects have occurred and continue to occur in several foreign geothermal fields and could cause severe problems in domestic areas of geothermal production. Subsidence and horizontal ground movements as great as have occurred in New Zealand or Mexico would be prohibitive in many areas of the United States. To determine the stress-strain parameters of these areas, and relate them to the extraction and injection of geothermal fluids, is of major concern in the exploitation of geothermal fields.

OBJECTIVE: To monitor, in cooperation with other agencies, vertical and horizontal displacements and land surface changes caused by geothermal fluid extraction and injection, induced subsurface pressure gradients, and formation temperature changes, in order to differentiate displacements and changes caused by geothermal development from those related to tectonic and near-surface effects; to analyze and interpret pertinent geodetic, geophysical and geologic data as a background for this investigation and to obtain the stress-strain parameters, and from these to appraise the behavior and operation of geothermal reservoir systems and the accompanying ground-water system.

APPROACH: In cooperation with other agencies, establish horizontal and vertical control networks around areas of geothermal exploitation and investigation, these to be surveyed periodically to measure horizontal and vertical movements. Determine stress-strain parameters of the geothermal systems and relate these to fluid withdrawals and tectonic effects; attempt to define the mechanics of the geothermal reservoir system.

PROGRESS AND RESULTS: (1) Extended the theory governing the interaction of rock stresses and pore pressure to non-isothermal environments such as geothermal reservoirs, radioactive waste disposal sites an hot dry rock systems. (2) Used micro earthquake data to study three dimensional geometry of the Geysers steam reservoir. (3) Developed a technique using precision gravity, geodetic and well test data to estimate drainage volume, mass decrease/unit volume and strain for subsurface reservoirs. (4) Completed the resurvey of the horizontal-control net in the Geysers area, Ca. (5) Resurveyed horizontal-control nets in Imperial Valley, Ca., Raft River, Id. and Roosevelt Hot Springs, Utah. (6) Resurveyed vertical-control nets in Geysers area, Ca. and Raft River, Id. The resurvey of the Cerro Prieto, Mexico Horizontal net indicated that as much a 6 cm/yr. of ground surface movement, resulting from fluid extraction, occurred

inwards toward the center of the production area. (7) Conducted reconnaissance of Dixie Valley, Nevada.

COMPLETED REPORTS:

Lofgren, B.E., 1977, Changes in aquifer-system properties with ground-water depletion: California Biennial Ground-Water Conf., 11th, Fresno, CA, Sept. 15-16, 1977, Proc., 37 p.

Lofgren, B.E., 1978, Monitoring crustal deformation in the Geysers-Clear Lake Geothermal Area, CA. Open File Report #78-597, 19 p.

Lofgren, B.E., Massey, B.L., Monitoring Crustal Strain, Cerro Prieto Geothermal Field, Baja California, Mexico. Open File Report #79-204, 33 p.

Massey, B.L., 1979, Regional and local networks of horizontal control, Cerro Prieto Geothermal area, Mexico. Open File Report #78-929, 6 p.

NR021 ANALYSIS OF GW SYSTEMS

PROJECT TITLE: ANALYSIS OF GROUND-WATER SYSTEMS

WRD PROJECT NO.: NR 71-021

LOCATION: Topical Research

PROJECT CHIEF: Tracy, James V.

HEADQUARTERS OFFICE: RESTON, VA

PROBLEM: Proper utilization and management of the ground-water environments, for either water resource or a potential waste environment, relies on preliminary and continuing assessment and identification of the environment. Improved, more generally applicable methods would provide a better assessment on which decisions can be made. Specifically, both analytic (mathematic) and numerical models, which adequately simulate the physics of observable phenomena related to ground-water flow and transport, provide useful frameworks in which self-consistent assessment can be made in regard to current or projected resource utilization.

OBJECTIVE: Improve and develop techniques utilized in the assessment of ground-water environments. These objectives include the consideration of appropriate mathematical models to explain various aspects of observed phenomena (e.g., dispersion), and improvement or development of the numerical methods which are consistent with and preserve the fundamental features of the physical and mathematical systems. General improvement is expected to be made in the reliability of assessment and/or prediction.

APPROACH: Application of applied mathematics, applied physics, and applied statistics to develop and evaluate effective methods to be utilized by current study programs. Evaluation of applicability of current numerical and mathematical models will be made utilizing existing data of the various phenomena. Request will be made of existing projects to gather more useful data to assist in this effort. Modifications of existing models or the development of more appropriate models will be made to analyze the current data available. This will then improve the general ability to analyse other data that may be gathered in the future.

PROGRESS AND RESULTS: Project personnel made a significant effort consulting on district and R.A.S.A. projects. Finite element flow and parameter estimation models were modified and supported on several projects. Some teaching was performed. Model documentation continued.

COMPLETED REPORTS:

Papadopulos, S.S. and Larson, S.P., 1978, Aquifer storage of heated water: Part II-Numerical simulation of field results: Ground Water, vol. 16, no. 4, pp. 242-248.

Tracey, J.V., 1979, A Review of Dispersion Modeling: Transactions of the American Nuclear Society, 1 p.

Posson, D.R., Hearne, G.A., Tracy, J.V. and Frenzel, P.F., 1980, A computer program for simulating geohydrologic systems in three dimensions OF-80-421, 795 p.

NR053 DIGITAL MODELING GROUND-WATER FLOW

PROJECT TITLE: DIGITAL MODELING OF GROUND-WATER FLOW

WRD PROJECT NO.: NR 75-053

LOCATION: NATIONWIDE

PROJECT CHIEF: LARSON, STEVEN P.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: PREDICTION OF THE MOVEMENT OF CONTAMINANTS IN A HYDROGEOLOGIC ENVIRONMENT REQUIRES KNOWLEDGE OF THE VELOCITY DISTRIBUTION OF THE TRANSPORTING FLUID. MANY TECHNIQUES HAVE BEEN ESTABLISHED AND IMPLEMENTED FOR SOLVING GROUND-WATER FLOW PROBLEMS AND CORRESPONDING VELOCITY DISTRIBUTIONS IN 2 DIMENSIONS. SOLUTIONS TO 3 DIMENSIONAL PROBLEMS OF PRACTICAL INTEREST HAVE BEEN INFREQUENT BECAUSE OF PROBLEM SIZE AND COMPUTATIONAL WORK REQUIRED. THE DETERMINATION OF FLUID VELOCITY DISTRIBUTIONS IN 3 DIMENSIONS WOULD PROVIDE THE NECESSARY FIRST STEP TOWARD INVESTIGATION OF THE MOVEMENT OF CONTAMINANTS IN 3-DIMENSIONAL GROUND-WATER PROBLEMS.

OBJECTIVE: THE OBJECTIVES OF THIS STUDY ARE TO DEVELOP NEW OR TO REFINE EXISTING GROUND-WATER FLOW MODELS FOR 3-DIMENSIONAL PROBLEMS. OPTIMUM MODEL EFFICIENCY IN TERMS OF COMPUTER CORE STORAGE AND COMPUTATIONAL WORK REQUIRED IS NECESSARY TO PERMIT APPLICATION TO FIELD PROBLEMS. THE RESULTING GROUND-WATER FLOW MODEL WILL BE USED TO DETERMINE 3 DIMENSIONAL VELOCITY DISTRIBUTIONS AND SUBSEQUENTLY PREDICTION OF 3 DIMENSIONAL MOVEMENT OF CONTAMINANTS IN SATURATED POROUS MEDIA.

APPROACH: VARIOUS NUMERICAL TECHNIQUES, SUCH AS SIP, ADI, AND LSOR, WILL BE EVALUATED AS TO THEIR UTILITY IN SOLVING 3-DIMENSIONAL GROUND-WATER FLOW PROBLEMS. AN OPTIMUM COMBINATION OF COMPUTER CORE STORAGE AND COMPUTATIONAL WORK REQUIRED WILL BE EMPHASIZED IN THE DEVELOPMENT OF NEW MODELS OR REFINEMENT OF EXISTING MODELS. THIS WILL REQUIRE EFFICIENT PROGRAMMING OF ALGORITHMS AND USE OF COMPUTER TECHNIQUES THAT MINIMIZE CORE STORAGE REQUIREMENTS. EMPHASIS WILL ALSO BE PLACED UPON MAKING THE RESULTANT MODEL OR MODELS APPLICABLE TO A WIDE VARIETY OF FIELD PROBLEMS WITHIN CONSTRAINTS IMPOSED BY PROBLEM SIZE AND COMPUTATIONAL WORK.

PROGRESS AND RESULTS: The development of the ground-water simulation model with modular structure was continued with initial program code generation. Other equation solving techniques, such as the conjugate gradient method, was evaluated as a related task. Special emphasis was given to schemes suitable for three-dimensional or multi-aquifer simulation problems. Documentation and refinement of recently completed computer codes such as (1) slice-successive over-relaxation, (2) finite-difference parameter estimation and (3) fresh-water, salt-water simulation was continued. Project has been suspended.

COMPLETED REPORTS:

Papadopulos, S.S. and Larson, S.P., 1978, Aquifer storage of heated water: Part II - numerical simulation of field results: Groundwater, vol. 16, no. 4, pp. 242-248.

Larson, S.P., 1979, Direct Solution Algorithm for the two Dimensional Ground-Water Flow Model: U.S. Geol. Survey, Open-File Rept. 79-202, 25 p.

Mercer, J.W., Larson, S.P., and Faust, C.R., 1980, Simulation of salt-water interface motion: Ground Water, v. 18, No. 4, p. 374-385

Mercer, J.W., Faust, C.F., and Larson, S.P., 1980, Finite-difference model to simulate the areal flow salt water and fresh water separated by an interface. U.S. Geol. Survey, Open File Rept. 80-407, 88 p.

NR072 TRANSIENT FLOW

PROJECT TITLE: TRANSIENT PHENOMENA AND THEIR APPLICATION TO GROUND-WATER FLOW PROBLEMS

WRD PROJECT NO.: NR 71-072

LOCATION: EASTERN MASSACHUSETTS

PROJECT CHIEF: MONGAN, CHARLES E.

HEADQUARTERS OFFICE: Cambridge, MA

PROBLEM: MANY SIGNIFICANT FLOWS IN NATURE TAKE PLACE IN NARROW PASSAGES UNDER UNSTEADY STATE CONDITIONS. LITTLE IS KNOWN OF THE MECHANISMS AND RELATIONSHIPS IN SUCH FLOWS. THE PROBLEM IS TO ANALYSE AND COMPUTE SUCH FLOWS WHICH MAY BE IDEALIZED SLIGHTLY TO MAKE THEM AMENABLE TO INVESTIGATION.

OBJECTIVE: THE OBJECTIVES OF THE INVESTIGATION ARE TO DEVISE MODELS REFLECTING THE REAL CONDITIONS. THEN TO ANALYZE AND COMPUTE THOSE MODELS. THE FURTHER OBJECTIVE IS TO COMPARE THE ANALYTICAL RESULTS WITH LABORATORY EXPERIMENTS. FINALLY, IT IS INTENDED TO RELATE THESE FINDINGS TO FIELD OBSERVATIONS.

APPROACH: THE PROBLEM HAS BEEN APPROACHED ON THREE LEVELS, FIRST: THE ANALYTICAL STUDY BASED ON FIRST PRINCIPLES IS UNDERWAY. SECOND: CALCULATIONS, USING THE LARGER COMPUTER ARE UNDERWAY. FINALLY: EXPERIMENTAL EQUIPMENT IS UNDER STUDY WHICH IS INTENDED TO CONFIRM THE RESULTS OF ANALYSIS.

PROGRESS AND RESULTS: A large part of project leader's time continued on the instrumentation involving contract work at the Draper Lab. A small amount of time was spent on consulting help to USGS personnel at the WRD Hydrologic Instrumentation Facility. In addition the following progress was made on ground-water flow studies: (a) Reshaping the manuscript, "Validity of Darcy's law under transient conditions," in response to colleague reviews, has taken longer than expected. Revision steps have been detailed and relayed to Research Advisor for added thought and comment. (b) Trial experiment runs on the two-dimensional transient flow apparatus at the manufacturer's facility have been delayed pending resolution of unexpected test set-up problems and delivery of supplemental hardware.

COMPLETED REPORTS:

Mamon, Glenn, Youmans, D.G., Sztankay, Z.G., and Mongan, C.E., 1978, Pulsed G & As laser terrain profiler: Appl. Optics, v. 17, no. 6, Mar. 15, p. 868-877, 15 figs.

NR089 Transport phenomena in porous media

PROJECT TITLE: Investigation of energy transport and associated mass transport in porous media involving both single and multiphase flow conditions

WRD PROJECT NO.: NR 78-089

LOCATION: Topical research

PROJECT CHIEF: Mercer, James W.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: The subsurface is used for a variety of applications that involve energy transport. Some of these are associated with energy development; for example, geothermal energy and heat storage. Others are associated with residuals management including radioactive waste disposal and waste heat injection. Many of these processes are directly related to associated mass transport problems and some involve multiphase flow. Although various studies have considered subsets of the above problems, a comprehensive methodology is needed to examine heat and mass transport in porous media involving both single and multiphase flow conditions.

OBJECTIVE: To analyze existing quantitative methods that describe energy and mass transport in porous media involving both single and multiphase flow; to modify and expand these methods, if necessary; and to apply these methods to a variety of related field problems.

APPROACH: The concepts of higher mathematics and statistics are applied to the problem of macroscopic description of porous media in order to develop the transport equations. Boundary and initial conditions and equation parameters are determined from field investigations. Digital models are then used to solve and analyze the initial boundary-value problems. Thus, the physical problem is replaced by an approximate mathematical model and field conditions are simulated using the digital computer.

PROGRESS AND RESULTS: Economics and power plant thermodynamics were coupled with a single-phase geothermal model to produce a management model for geothermal reservoirs. Among the interesting results was the anticipated conclusion that reinjection into low-permeable media can use up to 30% of the power produced, reducing the economic feasibility of development. An interface model for simulating the areal flow of salt water and fresh water separated by an interface was developed and tested. It was applied to a waste water injection field problem in Maui, Hawaii. Other progress includes: helped organize and host a Geological Society of America Penrose Conference on Heat Transport Processes in the Earth; helped organize and convene an American Geophysical Union Symposium on the Unsaturated Zone as a Barrier in Waste Disposal; was included in the Geological Survey Centennial (1979) lecture series made available to Sigma Xi chapters and clubs.

COMPLETED REPORTS:

Huyakorn, P.S.; Pinder, G.F.; Faust, C.R.; and Mercer, J.W., 1978, Finite Element Simulation on Two-Phase Flows in Porous Media, In Computational Techniques for interface problems: ASME, AMD, Vol 30, pp. 19-43, 25 p.

Li, Todd M.C.; Mercer, J.W.; Faust, C.R.; and Greenfield, R.J., 1979, Simulation of Geothermal Reservoirs Including Changes in Porosity and Permeability due to Silica-Water Reaction, in Kruger, Paul and Ramey, H.J., Jr., eds. Proceedings, Fourth Workshop on geothermal reservoir engineering, Dec. 13-15, 1978: Stanford University, Stanford, Calif., 5 p.

Faust, C.R. and Mercer, J.W., 1979, Geothermal Reservoir Simulation 1. Mathematical Models for Liquid- and Vapor-Dominated Hydrothermal Systems, Water Resour. Res. 15(1), pp. 23-30, 8 p.

Faust, C.R., and Mercer, J.W., 1979, Geothermal Reservoir Simulation 2. Numerical Solution Techniques for Liquid- and Vapor-Dominated Hydrothermal Systems, Water Resour. Res. 15(1), pp. 31-46, 16 p.

Mercer, J.W., and Faust, C.R., 1979, Reservoir Engineering and Evaluation, Proceedings, Geothermal Resources Council Symposium on Geothermal Energy and its direct uses in eastern United States, April 1979, 6 p.

Mercer, J.W., and Faust, C.R., 1979, Geothermal Reservoir Simulation 3. Application of Liquid- and Vapor-Dominated Hydrothermal Modeling Techniques to Wairakei, New Zealand, Water Resour. Res. 15(3), pp. 653-671, 19 p.

Mercer, J.W., and Faust, C.R., 1979, A Review of Numerical Simulation of Hydrothermal Systems, Hydrological Sciences Bull. 24 (3), pp. 335-344, 10 p.

WR025 TRANSPORT IN FLUID FLOW

PROJECT TITLE: TRANSPORT PROCESS IN FLUID FLOW

WRD PROJECT NO.: WR 70-025

LOCATION: Topical Research

PROJECT CHIEF: OGATA, AKIO

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Water, an effective carrier of heat energy, plays an important role in the distribution of heat near the earth's surface. To describe the transport process in porous materials, the interaction between the fluid in its liquid and vapor state with the granular material must be understood. For low temperature fluid the interactions are documented to some degree. However, in high temperature very little if any information is available. The problem, which requires investigation in both the saturated and unsaturated flow regimes, is most effectively investigated in two parts: Part A, Experimental and laboratory-scale model study of one- and two-phase systems at moisture contents appropriate for geothermal and high-level nuclear-waste studies; Part B, Theoretical study of equations describing single phase flow including change of phase.

OBJECTIVE: Determine the adequacy of the present limited description of the mechanism of energy transport by fluids in porous material and the various fluid-rock interactions due to temperature and pressure changes in the system, and develop a realistic model of energy transport in porous media. Part A, Experimental evaluation of theory of moisture movements due to temperature and pressure gradients and the effect of evaporation and condensation on the flow of moisture at elevated temperatures. Part B, Theoretical evaluation of significant parameters to obtain a simplified but realistic description of the transport process and to seek solutions of these differential equations.

APPROACH: Part A, Experimental studies involve the use of laboratory-scale models of moisture movement due to a heat source in a high-temperature and high-pressure environment. Measurements of moisture contents and pressure will entail methods developed by soil physicist. Data generated will provide information on effects of adsorption, evaporation and condensation. Part B, Theoretical studies consist of determining applicability of various approximate techniques such as perturbation method to single-phase flow equation with moving or fixed boundaries.

PROGRESS AND RESULTS: Laboratory experiments show that the influence of temperature upon flow in unsaturated soil is significantly larger than present theory predicts. Small-scale lab investigations of steamflow in porous material showed that adsorption (or absorption) of steam modified pressure-transient behavior markedly. Dependence of this adsorption lag effect upon several system parameters was studied, and good agreement was achieved between the experiments and a numerical model which included a vapor adsorption

effect.

COMPLETED REPORTS:

Moench and Ogata, 1980, A numerical inversion of Laplace transform solution to radial dispersion, Water Resources Research, 5 p.

Herkelrath, W.N., 1978, The "heat-pipe" effect in vapor-dominated geothermal system: Proc. Third Workshop Geothermal Reservoir Engineering, Stanford U., Dec. 14-16, 1977, pp. 43-48.

Moench, A.F. and Herkelrath, W.N., 1978, The effect of vapor-pressure lowering upon pressure drawdown and buildup in geothermal steam wells: Transactions of the Geothermal Resources Council Annual Meeting, Hilo, HI, July 25-27, 1978, pp. 465-468.

Constantz, "Temperature dependence of soil water movement during steady evaporation" in 1979 Agronomy Abstracts.

WR102 Modeling hydrothermal systems

PROJECT TITLE: Numerical modeling of hydrothermal convection systems

WRD PROJECT NO.: WR 73-102

LOCATION: Topical Research

PROJECT CHIEF: SOREY, MICHAEL L.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Mathematical analysis of heat and fluid flow in alternative conceptual models of hydrothermal convection systems is needed to understand the natural conditions of fluid flow in areas with potential for geothermal energy development. Such a modeling effort, involving both numerical and analytical solution techniques, can provide a more realistic assessment of the recoverable energy in specific areas and the effects of development on existing thermal springs and groundwater resources. Data needed to develop valid models of these systems must come from associated geologic, geophysical, geochemical, and hydrologic studies, and from analysis of well test data where available.

OBJECTIVE: Verify and modify existing numerical codes which solve heat and mass balance equations for single- and two-phase flow in two and three dimensions. Develop and analyze quantitatively conceptual models of several typical hydrothermal systems. Develop techniques for analyzing well tests under two-phase conditions. Assist in an assessment of the low temperature (20 degrees C and 90 degrees C) geothermal resources in the United States.

APPROACH: Combine detailed modeling studies of a few typical hydrothermal systems with theoretical studies of natural convection and upflow in hot spring conduits to assess the geothermal resources in these areas and to develop useful constraints on circulation depths and areal extents applicable to other areas. Modeling studies are completed or in progress on the hydrothermal systems in Long Valley caldera, CA, Leach Hot Springs in Grass Valley, NV, and Raft Rivers, ID. Theoretical work on well transients under two-phase reservoir conditions is also being carried out to enable data from flow tests on deep exploration wells to be used to determine reservoir properties.

PROGRESS AND RESULTS: (1) Completed post-doctorate fellowship research in New Zealand. (2) Wrote two papers on two-phase well test analysis and lumped-parameter modeling of the Wairakei geothermal field. (3) Developed a set of test problems for a numerical code comparison project sponsored by DOE. (4) Partially completed modeling study of the geothermal reservoir at Raft River, ID. (5) Prepared open-file report on the hydrothermal system in Grass Valley, NV.

COMPLETED REPORTS:

Sorey, M.L., Lewis, R.E., and Olmsted, F.H., 1978, The hydrothermal system of the Long Valley caldera, U.S. Geol. Survey Professional

Paper 1044-A, 60 p.

Sorey, M.L., 1978, Numerical Modeling of liquid geothermal systems, U.S. Geol. Survey Paper 1044-D, 25 p.

Fournier, R.O., Sorey, M.L., Mariner, R.H., and Truesdell, A.H., 1979, Geochemical prediction of aquifer temperatures in the geothermal system at Long Valley, CA, Journal of Volcanology and Geothermal Research, v. 5, p. 17-34, 10 p.

WR127 ENERGY TRANSPORT IN GW

PROJECT TITLE: MATHEMATICAL MODELING OF ENERGY TRANSPORT IN MULTIPHASE GROUND-WATER SYSTEMS

WRD PROJECT NO.: WR 75-127

LOCATION: NATIONWIDE

PROJECT CHIEF: MOENCH, ALLEN F.

HEADQUARTERS OFFICE: MENLO PARK, CA

PROBLEM: Subsurface formations serve as conduits, barriers, and reservoirs for water and heat energy. Meteoric water percolates through openings in the rock and exchanges heat with its environment as it moves. The physics involved in the simultaneous transfer of mass and energy in porous or fractured rock under multiphase conditions is not fully understood.

OBJECTIVE: Predict temperature and pressure distributions in single-phase and multiphase ground-water systems under natural and stressed conditions. Determine rates of water and heat movement in subsurface formations under natural and stressed conditions. Test equations developed for physical realizability.

APPROACH: Numerical and analytical techniques are used to simulate field and laboratory, transient pressure and temperature data. Controlling equations are developed and modified, as necessary, to account for the physical processes which occur in earth materials. Laboratory results are used to test and verify models developed. Field data are used for case studies.

PROGRESS AND RESULTS: A fissure-block model has been developed for vapor-dominated geothermal reservoirs. This work was motivated initially to explain long-term steam production at the Geysers and subsequently to suppport the hypothesis that seismicity at the Geysers can be related to steam production through a knowledge of pore-pressure gradients and thermal stresses. A paper on this subject was presented in San Francisco by Roger Denlinger at the 1979 AGU Fall Meeting, Dec. 3-7, (Denlinger and Moench, abstract T94). A simpler version of the above model wherein the blocks bounding the fissure were considered impermeable but capable of conducting heat was used to analyse a pressure buildup test from an Italian geothermal well. The results were published with G. Neri (ENEL) in the Proceedings of the 5th Workshop on Geothermal Reservoir Engineering, Stanford, Dec. 12-14. A technique for inverting the Laplace transform solution to linear flow problems was applied to the radial dispersion of chemicals injected into ground-water systems. A paper on this subject was presented in San Francisco at the 1979 AGU Fall Meeting, Dec. 3-7 (Moench and Ogata, abstract H94). The paper was submitted for publication in Water Resources Research. Laboratory experiments conducted by W.N. and Herkelrath involving steam adsorption under superheated conditions have been successfully simulated at temperatures ranging from 100 degrees C to 146 degrees C.

COMPLETED REPORTS:

Moench, A.F. and Atkinson, P.G., 1978, Transient pressure analysis in geothermal steam reservoirs with an immobile vaporizing liquid phase-summary report: Proc. 3rd Workshop on Geothermal Reservoir Engineering, Stanford, CA, Dec. 14-16, 1977, pp. 64-69.

Moench, A.F. and Herkelrath, W.N., 1978, The effect of vapor-pressure lowering upon pressure drawdown and buildup in geothermal steam wells: Transactions of the Geothermal Resources Council Annual Meeting, Hilo, HI, July 25-27, 1978, pp. 465-468.

Moench, A.F., 1978, The effect of thermal conduction upon pressure drawdown and buildup in fissured, vapor-dominated, geothermal reservoirs: Proc. 4th Workshop on Geothermal Reservoir Engineering, Stanford, CA Dec. 13-15, p. 112-117, 6 p.

Herkelrath, W.N. and Moench, A.F., 1978, Laboratory investigations of steam pressure-transient behavoir in porous materials: Proc. 4th Workshop on Geothermal Reservoir Engineering, Stanford, CA Dec. 13-15, p. 54-59, 6 p.

Moench, A.F. and Atkinson, P.G., 1978, Transient pressure analysis in geothermal steam reservoirs with an immobile vaporizing liquid phase: Geothermics, V. 7, No. 7/8/9, p. 253-264, 11 p.

Moench, A.F., 1979, Radial steam flow in two-phase geothermal reservoirs - comparison of analytical and finite-difference solutions for transient pressure drawdown: Preprint of paper presented at 1979 Calif. Regional Meeting of the SPE of AIME, Ventura, CA, Apr. 18-20, 1979, 8 p.

Moench, A.F. and Neri, G., 1979, Analysis of Gabbro In Steam Pressure Buildup Test: Proc. of 5th Stanford Workshop on Geothermal Reservoir Engineering, Stanford, CA Dec. 12-14, p. 99-105, 6 p.

CR027 THERMAL POLLUTION

PROJECT TITLE: THERMAL POLLUTION OF RESERVOIRS AND STREAMS

WRD PROJECT NO.: CR 68-027

LOCATION: NATIONWIDE

PROJECT CHIEF: HARBECK, G. EARL, JR.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Problem or need for study: Thermal pollution of streams and reservoirs is getting to be an increasingly important problem, and will become critical in some areas with the increase in the number of nuclear powerplants that are already planned. Legal restrictions are being imposed upon industries adding heat to rivers and lakes, and information is needed to provide a basis for those restrictions.

OBJECTIVE: The objectives are to provide techniques for estimating the pattern of temperature distribution in a lake or the downstream temperature die-away pattern in a river resulting from the use of water for cooling in a powerplant. These techniques are being used to estimate increased evaporation and thermal pollution resulting from the addition of heat by a powerplant in reviewing proposed plant designs for EPA.

APPROACH: The relationships among the various physical processes returning energy to the atmosphere are being studied in order to assess the possible effects of a proposed powerplant.

PROGRESS AND RESULTS: Many detailed proposals and plans for construction of nuclear and fossil-fuel steam plants were reviewed to determine whether the estimates of increased evaporation and temperature rise that would be caused by the proposed plants are reasonable. The plant designs were also reviewed to estimate the possible icing effects, if any, on highways in the vicinity. A number of scientific papers, perhaps 20 in all, were reviewed or referred to other hydrologists in universities or in other Federal agencies for review, with opinions requested as to the suitability of the papers for publication.

CR200 Unsaturated Zone Field Studies

PROJECT TITLE: Field Applications of Unsaturated Zone Flow Theory

WRD PROJECT NO.: CR 69-200

LOCATION: Southern High Plains of Texas

PROJECT CHIEF: Weeks, Edwin P.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: Knowledge of flow through the unsaturated zone is needed to evaluate natural recharge, and return flow from irrigation, and the impact of land use changes on recharge and overland runoff. In addition, such knowledge is needed to evaluate water management schemes involving artificial recharge and vegetation or water-table manipulation to increase water supply. Finally, unsaturated flow-theory is needed to evaluate pollution hazards from surface sources. Although much research has been done on unsaturated flow phenomena, operational methods are lacking for many of the above problems.

OBJECTIVE: To develop and test methods for field measurement of hydraulic head, saturated and unsaturated hydraulic conductivity, and moisture content in the unsaturated zone. To develop and test and operational computer program for simultion of saturated-unsaturated flow phenomena on a structure-imitating basis for small-scale problems, and a more empirical watershed-type model for large scale problems.

APPROACH: Various methods for field determination of hydraulic parameters in the unsaturated zone will be tested at field experimental sites. Experiments will also be conducted at these sites to test the simulation models being developed by the project staff.

PROGRESS AND RESULTS: (1) A basic data report on the tracer tests performed at Stanton, Texas, was completed, as was a report for WRI release documenting radialg round-water transport models. (2) Instrumentation for measuring effects of recharge under natural and irrigated conditions was completed at a shaft installation in the Nebraska Sand Hills, as was instrumentation at a separate site for measuring effects of anisothermal water flow due to a cylindrical buried heat source. Data collection was started at both sites. (3) Construction was started on a sand-barrel experiment to measure effects of radial anisothermal heat transfer away from a heat source (4) Sampling soil gases for CO(2) and **14CO(2) content was continued in Texas and North Dakota. Diffusion modeling of the fluorocarbon contents measured in unsaturated-zone gases was completed, and **14CO(2) diffusion modeling was completed to the point that effects of unidentified chemical processes were isolated.

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Weeks, E.P., 1978, Field determination of vertical permeability to air in the unsaturated zone: U.S. Geol. Survey Prof. Paper 1051, 41 p.

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Weeks, E.P., 1979, Some principles of flow in the unsaturated zone as related to artificial recharge: Proceedings of Groundwater Recharge Symposium, Salt River Project, Phoenix, Arizona, 16 p., 25 fig.

Signor, D.C., 1979, Artificial groundwater recharge case histories in the Texas Southern High Plains. Proceedings of Groundwater Recharge Symposium, Salt River Project, Phoenix, Ariz., 16 p. 25 figs.

Grove, D.B., and Wood, W.W., 1979, Prediction and field verification of subsurface-water quality changes during artificial recharge, Lubbock, Texas: Ground Water, v. 17, no. 3, p. 250-257, 7 p.

CR255 Pecos Evapotranspiration Studies

PROJECT TITLE: Evapotranspiraton studies in the Pecos River floodplain, New Mexico

WRD PROJECT NO.: CR 79-255

LOCATION: Pecos River floodplain, New Mexico

PROJECT CHIEF: Weeks, Edwin P.

HEADQUARTERS OFFICE: Denver, CO

PROBLEM: In 1967, USBR began clearing saltcedar from 19,000 acres in a reach of the Pecos River floodplain extending from Acme to Artesia, New Mexico, with the anticipation that 28,000 acre-feet of water would be salvaged, as indicated by WSP 1659. However, studies conducted by G. E. Welder, New Mexico WRD, of baseflow gain in the reach from 1947 until 1978 indicate that salvage was instead too small to detect by that method. Because total baseflow gain in the reach from 1964 to present has ranged from 10,000 to 20,000 acre-feet per year, salvage of as little as 10,000 acre-feet per year probably could be detected.

OBJECTIVE: This project is designed to test the hypothesis that the original estimates of evapotranspiration from saltcedar were too high, and/or the estimates from bare soil and shallow-rooted replacement vegetation were too low. If this hypothesis proves true, the failure to detect salvage can be explained.

APPROACH: Evapotranspiration from a site with a baresoil or shallow-rooted vegetative cover and from a site with mature saltcedar cover will be measured. Three methods will be used to measure evapotranspiration from the bare-soil site. For one method, vertical hydraulic between the bottom of the root zone and the water table head gradients will be recorded by transducer-equipped tensiometers. Unsaturated hydraulic conductivity of the laboratory and field methods, and upward flux from the water table will be computed using equations given in WSP 2021 A. In the second and third approaches, evapotranspiration will be measured by energy-budget and eddy-correlation methods, respectively.

PROGRESS AND RESULTS: Estimates of evapotranspiration were made from sites in the flood plain of the Pecos River from which saltcedar had been cleared near Artesia, New Mexico, and which supported shallow-rooted weeds in October 1979 and in June and August 1980. The measurements were made using eddy-correlation equipment developed for the U.S. Geological Survey. The instrumentation was substantially modified following the October 1979 test, and is approaching operational status. Other measurements were made over nearby saltcedar groves at sequential times. Other sets of measurements were made using the same equipment at Water and Power Resources Service test and control plots in the closed basin of the San Luis Valley in Colorado. Weather stations to collect data for use in the Penman equation were installed at one site each in the Pecos River valley and the closed basin in Colorado to allow extrapolation of the eddy-correlation

measurements in time. Tensiometer installations were also made at two nearby sites with shallow-rooted vegetation or bare soil to independently estimate upward movement of water from the water table based on the soil equation. Aerial photographs were taken to aid in extrapolating measurements areally.

COMPLETED REPORTS:

Fritschen, L.J., Simpson, J.R., and Smith, M.O., 1980, Eddy-correlation measurements of evaporation from bare soil and of evapotranspiration from saltcedar groves in the Pecos River flood plain, New Mexico: Final Report, U.S. Geol. Survey Grant No. 14-08-001-G-608, 45 p.

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NR067 Fractured Hydrogeologic Systems

PROJECT TITLE: Analysis of Mechanical and Thermal Water-Rock Interactions in Fractured Hydrogeologic Systems

WRD PROJECT NO.: NR 78-067

LOCATION: Topical Research

PROJECT CHIEF: Faust, Charles R.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: Management of hydrogeologic systems for diverse purposes such as water supply, waste disposal, heat storage, and geothermal energy requires quantitative methods for determining the effects of water-rock interactions on the behavior of the system. Emphasis in quantifying these effects has been directed to porous media. Application of porous media models to fractured hydrogeologic systems is not always reliable. Furthermore, available techniques devised for fractured media are, in general, impractical and have not been sufficiently field-tested. There is a need to evaluate the available techniques and to devise more reliable and practical methods for analyzing fractured hydrogeologic systems.

OBJECTIVE: To evaluate existing quantitative methods for describing and predicting the effects of thermal and mechanical water-rock interactions on the behavior of fractured hydrogeologic systems. To improve existing techniques and/or devise new techniques as required.

APPROACH: Evaluation and improvement of existing quantitative methods and/or development of new techniques for analysis of fractured hydrogeologic systems will require the use of higher mathematics, statistics, digital models, and carefully designed field studies. Emphasis will be placed on techniques having immediate applications and for which a need has been established in current field study programs.

PROGRESS AND RESULTS: (1) Completed literature review of nonisothermal transport processes in unsaturated porous media. (2) Completed rough draft of report on governing equations for nonisothermal transport in unsaturated porous media. (3) Developed one and two dimensional numerical models to solve nonisothermal, unsaturated transport problems. (4) Began study of mechanical behavior of shales during erosional unloading.

COMPLETED REPORTS:

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WR024 INFILTRATION AND DRAINAGE

PROJECT TITLE: APPLICATION OF THE UNSATURATED FLOW THEORY TO THE PHENOMENA OF INFILTRATION AND DRAINAGE

WRD PROJECT NO.: WR 63-024

LOCATION: Topical Research

PROJECT CHIEF: RUBIN, JACOB

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Surface runoff and various ground-water processes are often significantly influenced by water flow in the unsaturated zone. For many situations of hydrologic interest, inadequate knowledge prevents these influences from being taken properly into account in water resources analyses.

OBJECTIVE: To adapt, further develop, and utilize present theories of fluid flow through unsaturated porous media, and in particular those of infiltration and drainage, so as to make these theories more useful in the analyses of ground water, runoff, and other hydrologic problems.

APPROACH: Test experimentally the validity and accuracy of present theories of fluid flow in unsaturated porous media. Devise improved laboratory and field methods for measuring such flows and for evaluating the flow-determining parameters of soils and sediments. Develop computer-aided theoretical analyses of the interactions between unsaturated-zone waters and ground or surface waters. Test experimentally, in the laboratory and in the field, the applicability of the analyses and methods developed. In the field tests, study flows of unsaturated zone water in settings relevant to hydrologic problems involving ground-water recharge, surface-runoff formation, or movement of radioactive and chemical pollutants.

PROGRESS AND RESULTS: Laboratory infiltration experiments that were carried out with the inflowing water at subatmospheric pressures seemed to demonstrate a certain inadequacy in the Richards' equation. The same kind of inadequacy was shown previously by experiments with controlled surface fluxes. A laboratory system for measuring air permeability and associated air conducting properties of soils with constant water content was built and successfully tested with relatively dry soils. Development of a method for measuring quickly the hydraulic conductivity of unsaturated soil cores was begun. A computer based, theoretical analysis of this methods feasibility has shown very promising results. Assembly was started on the equipment needed for utilizing the above method in field investigations of downward water fluxes in deep unsaturated zones of arid regions.

COMPLETED REPORTS:

CR092 HYDROLOGY DEFINED BY RAINFALL SIMULATION

PROJECT TITLE: HYDROLOGIC EFFECTS OF SURFACE MINING, LAND REHABILITATION, AND LAND USE AS DEFINED BY RAINFALL SIMULATION

WRD PROJECT NO.: CR 74-092

LOCATION: Topical research

PROJECT CHIEF: LUSBY, GREGG C.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: THE DEMANDS FOR MULTIPLE USE OF PUBLIC LANDS IN WESTERN UNITED STATES AND THE ADJACENT OR INTERMINGLED PRIVATE LANDS HAVE POINTED UP THE NEED FOR QUANTITATIVE HYDROLOGIC DATA IN MANY AREAS. THESE DATA ON RUNOFF, SEDIMENT YIELD, AND SOIL-VEGETATION CHARACTERISTICS ARE NECESSARY IN ORDER TO EVALUATE THE IMPACT OF A VARIETY OF LAND USES, SUCH AS SURFACE MINING, RECREATION, AND INDUSTRIAL SITINGS. IN MOST CASES, THE DATA NEEDED FOR EVALUATIONS ARE NOT AVAILABLE OR WOULD REQUIRE SEVERAL YEARS TO GATHER. THEREFORE, METHODS MUST BE DESIGNED THAT WILL PERMIT MORE RAPID COLLECTION OF THE NECESSARY BASIC DATA.

OBJECTIVE: (1) Quantitative characterization of a variety of soil-vegetation complexes with regard to surface flow, sediment yield, and susceptibility to erosion, (2) Determination of basic processes controlling runoff and erosion from upland areas, (3) Determination of the effects of various types of land use, and (4) Determination of measurable physical properties of watersheds which provide useful input to rainfall-runoff and erosion models.

APPROACH: The basic tool to be used in the study is a rainfall simulator which allows rainfall to be applied and measurements made on natural drainage basins of about 4,000 square feet. Instrumentation will be installed in several simulator study watersheds within a larger drainage basin to obtain comparisons of runoff and sediment yield resulting from natural precipitation events. Specific items to be studied within the simulation plots include variables and parameters in the Green-Ampt infiltration equation. The objective of these studies is to determine the relationship between measurable physical characteristics on the infiltration plots and the parameters in order to extrapolate the plot data to larger areas through use of rainfall-runoff and erosion models.

PROGRESS AND RESULTS: Rainfall simulator data was obtained at the Coal Creek EMRIA study watershed near Atoka, Oklahoma. Ten simulator runs at five different locations within the watershed were made to determine runoff and erosion characteristics of soils in the area. Data was compiled and a report was prepared summarizing these data. Simulation data was obtained at six sites at the Prairie Dog Creek EMRIA study watershed near Birney, Montana. Investigations into the utilization of simulation data for determining parameters and variables in infiltration equations were continued.

COMPLETED REPORTS:

CR196 Hydrologic Remote Sensing

PROJECT TITLE: Application of Satellite and Aircraft Data to Hydrology

WRD PROJECT NO.: CR 73-196

LOCATION: Topical Research

PROJECT CHIEF: MOORE, GERALD K.

HEADQUARTERS OFFICE: Sioux Falls, SD

PROBLEM: Remote sensing has considerable potential for hydrologic studies, particularly in the visible, infrared, and microwave parts of the spectrum. It offers new information and new tools to the hydrologist and can reduce the field work necessary in conventional studies. Research, testing, and development are needed to obtain operational procedures, however.

OBJECTIVE: (1) Conduct research on the applications of remote sensing to ground-water occurrence, surface drainage characteristics, and water color and turbidity. Develop application examples. (2) Develop enhancement and interpretation procedures for remote sensing imagery and digital data, using both manual and computer processing. (3) Train and consult with other hydrologists on feasibility tests and operational uses of remote sensing. (4) Originate, plan, and coordinate programs and projects in remote sensing.

APPROACH: (1) Analyze existing data for hydrologic information; develop procedures for information extraction. Evaluate effects of atmosphere and soil and vegetation cover. (2) Evaluate existing procedures for manual and digital processing. Determine need and utility of new procedures. (3) Conduct training courses and briefings. (4) Work with WRD, EROS, and NASA personnel to originate and coordinate remote sensing applications to hydrologic problems.

PROGRESS AND RESULTS: Two training courses in Hydrologic Remote Sensing were given to WRD personnel and others. A day of training was given at a BLM course on ground-water exploration. Formal talks were given to a statewide ASCE Meeting and a statewide AWRA meeting. Digital processing was completed for personnel from three WRD districts; other work of this type is scheduled or planned. Consultation services were provided on aquifer recharge, ground-water occurrence, and water pollution problems. Research began on digital enhancement of fracture patterns and on hydrologic significance of drainage characteristics.

COMPLETED REPORTS:

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Moore, G.K., 1978, Satellite surveillance of physical water quality in International symposium on remote sensing of environment, Manilla,

Phillippines, 12th, 1978, Proceedings, Ann Arbor, Michigan, Environmental Research Institute of Michigan, v.i, p. 445-62, 18 p.

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Heimes, F.J., Moore, G.K., and Steele, T.D., 1978, Preliminary applications of Landsat images and aerial photography for determining land use, geologic, and hydrologic characteristics--Yampa River basin, Colorado and Wyoming: U.S. Geol. Survey Water Resources investigations rpt. 78-96, 48 p.

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Moore, G.K., (1979), The role of remote sensing in ground-water exploration in Joint Indo-US workshop on remote sensing of water resources, Hyderabad, India, 1978, Proceedings: Secunderabad, India, National Remote Sensing Agency, p. 22-40, 19 p.

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Moore, G.K., 1979, The role of remote sensing in ground-water exploration in Seminar on remote sensing applications and technology transfer for international development, Michigan, 1979, Selected papers: Ann Arbor, Michigan, Environmental Research Institute of Michigan, p. 57-64

CR228 Rainfall-Runoff Modeling

PROJECT TITLE: Precipitation-Runoff Modeling of Watershed Systems

WRD PROJECT NO.: CR 77-228

LOCATION: Tropical Research

PROJECT CHIEF: Leavesley, George H.

HEADQUARTERS OFFICE: Lakewood, CO

PROBLEM: (1) Changing land-use patterns coupled with natural variations in precipitation generate many questions regarding the hydrologic consequences of various combinations of land use and precipitation. To adequately predict and assess the effects of current or proposed land uses on basin hydrology, a hydrologic modeling system is required. (2) Eruptions of Mt. St. Helens have deposited large quantities of volcanic ash in major tributary basins to the Columbia River. To estimate the effects of this ash on runoff and erosion rates an understanding of the infiltration and erosion processes taking place on the ash deposits must be obtained.

OBJECTIVE: (1) (a) develop, test, and verify a hydrologic modeling system to predict basin runoff, sediment yields, and general basin hydrology from normal and extreme rainfall and snowmelt events occurring on various combinations of land use. (b) develop a statistical theory of errors for the modeling system. (c) improve model and data collection techniques to minimize model error components. (d) test and verify modeling system on basins across the U.S. (2) (a) determine the infiltration and erosion characteristics of volcanic ash on selected study plots. (b) extrapolate plot study results to a larger basin area on a limited basis using hydrologic model simulations.

APPROACH: (1) A modular hydrologic modeling system will be developed. Each module will represent one component of the hydrologic system. Modules will be developed, tested, and verified for the major climatic and physiographic regions of the U.S. Sources of model error will be assessed and the transfer of these error components through the modeling system will be evaluated. Techniques for estimating model parameters from physical data will be developed. (2) A rainfall simulator will be used to investigate infiltration and erosion as a function of ash characteristics, surface slope, rainfall intensity, and antecedent moisture. A permanent plot will monitor changes in infiltration and erosion through time under natural rainfall events.

PROGRESS AND RESULTS: The first phase of development of the Precipitation-Runoff Modeling System was completed and the System was implemented on the USGS computer facilities. A users manual was drafted and is being reviewed. Model testing and verification was begun on selected coal study basins. An analysis of the input errors in precipitation-runoff models was examined with regard to their influence on runoff predictions and parameter estimates. Study results were evaluated and are being published in a comprehensive report. A small basin near Denver was selected and instrumented to begin

evaluation of several rainfall simulators for their potential applicability to estimating hydrologic model parameters. Test sites were selected in the Shultz Creek and Iron Creek drainage basins near Mt. St. Helens and will be used to investigate the infiltration and erosion characteristics of recent volcanic ash deposits.

NR054 Network design

PROJECT TITLE: Design of hydrologic data networks

WRD PROJECT NO.: NR 76-054

LOCATION: Topical

PROJECT CHIEF: MOSS, MARSHALL E

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: There is a strong need to develop methodologies by which WRD's hydrologic-data-collection activities can be objectively evaluated and modified when necessary in order that the efficiency of its operations will be maximized.

OBJECTIVE: The project will attempt to develop objective methodologies for hydrologic network design and will assist in the transfer of network-design technologies by performing case studies.

APPROACH: The project will use computer simulations of hydrologic processes in order that statistical and economic measures of the hydrologic-data collection programs can be evaluated. The unknown hydrologic and economic parameters will be treated by means of Bayesian statistical techniques and sensitivity analysis.

PROGRESS AND RESULTS: Techniques were developed to analyze the cost effectiveness of streamgaging networks in the Lower Colorado River Basin, and a case study was completed of the operations conducted out of the Blythe, Calif., field office. Studies of improved regression techniques were completed. Consultation with districts using the NARI technique were continued.

COMPLETED REPORTS:

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Tasker, G.D., and Moss, M.E., 1979, Analysis of an Arizona flood-data network for regional information: Water Resources Research, v. 5, no. 6, pp. 1791-1796, 6 p.

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NR061 HYDROLOGIC PROBABILITY MODELS

PROJECT TITLE: HYDROLOGIC PROBABILITY MODELS

WRD PROJECT NO.: NR 69-061

LOCATION: tropical research

PROJECT CHIEF: KIRBY, WILLIAM H.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: INTERRELATIONSHIPS BETWEEN DETERMINISTIC PHYSICAL LAWS AND PROBABILISTIC DESCRIPTIONS OF HYDROLOGIC PHENOMENA ARE POORLY UNDERSTOOD. THUS THERE IS NO GENERALLY ACCEPTED FRAMEWORK FOR COMBINING THESE COMPLEMENTARY APPROACHES TO HYDROLOGIC PROBLEMS. THE LACK OF SUCH A FRAMEWORK HINDERS PROGRESS IN AREAS AS DIVERSE AS FLOOD FREQUENCY ANALYSIS, RESERVOIR DESIGN AND OPERATION, AND ASSESSMENT OF DATA ADEQUACY FOR ENGINEERING/ECONOMIC SYSTEM DESIGN.

OBJECTIVE: The objectives of this project are: to develop a conceptual framework for joint consideration of deterministic and probabilistic factors in hydrology and water management; to explain and illustrate this framework by formulating and solving idealized problems in flood frequency analysis, reservoir management, and data evaluation; and to develop improved analytical techniques in these areas.

APPROACH: The approach will be to mathematically formulate and analyze specific idealized problems in the three areas of interest. Digital computation will be used as necessary for solving or evaluating the resulting equations or formulas. The general theory sought will be developed as necessary to summarize and unify experience with the specific problems.

PROGRESS AND RESULTS: (1) Compared statistical reliabilities of flood frequency analyses based on annual-flood data series and partial-duration data series using Monte Carlo simulation. For high return periods (100 yr) and record lengths of 10-50 years, the estimated exceedance probabilities based on annual peaks had random sampling errors ranging from 80 percent to 200 percent. The corresponding errors for the partial-duration series were about half as large (which still are very large). Increasing the partial-duration sample beyond 3 or 4 peaks per year gave negligible improvement in accuracy. (2) Set up computer subroutine libraries on the IBM and Reston Harris computers. The libraries contain routines for computing probability distributions, generating quasirandom samples, etc.

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SR028 Deterministic SW Models

PROJECT TITLE: Deterministic Models of Surface-Water Systems

WRD PROJECT NO.: SR 73-028

LOCATION: SOUTHERN MISSISSIPPI

PROJECT CHIEF: JENNINGS, MARSHALL E.

HEADQUARTERS OFFICE: NSTL Station, MS

PROBLEM: THE LACK OF OPERATIONAL MODELS OF SURFACE-WATER SYSTEMS THAT CAN BE USED IN WATER-RESOURCES INVESTIGATIONS.

OBJECTIVE: The primary project objective is to develop, test, document, and make operational, state-of-the art computer models of surface water systems including flow-quantity and flow-quality aspects of stream, reservoir and estuary systems. Corollary objectives are definition of criteria for data collection and effective data-base management to support operational modeling of surface-water systems.

APPROACH: Studies of flow processes including reservoir regulation and routing, flow routing and ground-water interaction will be made. In addition water quality processes, including chemical and biological reaction and transport will be studied. Models of flow and water quality processes will be tested with field data and placed on the WRD computer system.

PROGRESS AND RESULTS: Urban stormwater studies using data on four small sites near Miami, Florida were concluded. A COE-sponsored study of five one-dimensional water-quality models using three USGS data sets, and dam-break analyses of the Toccoa Falls and Mt. St. Helens disasters, along with associated computer programs, have been completed. An assessment of surface-water coal-hydrology models foru se in WRD districts was begun and an initial report was completed. A data management system and associated stormwater models for use in USGS/EPA urban studiesw as developed and is ready for testing.

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SR066 TECHNIQUES FLOOD PLAIN MAPPING

PROJECT TITLE: TECHNIQUES OF FLOOD-PLAIN MAPPING FOR LAND-USE MANAGEMENT OF FLOOD PLAINS

WRD PROJECT NO.: SR 72-066

LOCATION: NATIONWIDE

PROJECT CHIEF: Brown, Russell H.

HEADQUARTERS OFFICE: Bay St. Louis, MS

PROBLEM: IDENTIFICATION OF LANDS SUBJECT TO FLOODING IS NECESSARY FOR LAND-USE MANAGEMENT ON FLOOD PLAINS. ACCURATE DELINEATION ON MAPS, OF AREAS SUBJECT TO INUNDATION BY FLOODS OF A GIVEN FREQUENCY IS REQUIRED--INFORMATION ON FREQUENCY OF FLOOD DISCHARGES, PROFILES OF WATER-SURFACE ELEVATIONS ALONG THE CHANNEL, AND LARGE-SCALE TOPOGRAPHIC MAPS. INFORMATION OBTAINED DURING FIELD SURVEYS IS NEEDED FOR COMPUTING WATER-SURFACE PROFILES BY STEP-BACKWATER PROCEDURES. NEW TECHNIQUES OF PHOTOGRAMMETRY, ELECTRONIC MEASUREMENT FROM AIRCRAFT, COMPUTATION OF BACKWATER PROFILES, AND THE PLOTTING OF MAPS AND CROSS SECTIONS BY COMPUTER MAY OFFER MORE EFFICIENT MEANS OF FLOOD-PLAIN DELINEATION.

OBJECTIVE: TO EVALUATE POTENTIAL FLOOD-MAPPING TECHNIQUES, APPRAISE THEIR ACCURACY IN RELATION TO COST FOR VARIOUS USES AND TIME FRAME IN WHICH FLOOD-PLAIN MAPS ARE OF MAXIMUM USE, AND TO INVESTIGATE MEANS TO CARRY OUT FLOOD-MAPPING TECHNIQUES AT AN ACCELERATED RATE.

APPROACH: INVESTIGATE AND COMPARE AVAILABLE METHODS OF OBTAINING DATA REQUIRED FOR PREPARING MAPS, CHARTS, AND INTERPRETIVE REPORTS ASSOCIATED WITH IDENTIFICATION OF FLOOD-PRONE AREAS. DETERMINE THE RANGE IN COSTS INVOLVED IN THE CONVENTIONAL AERIAL PHOTOGRAPHY-STEREO MODEL APPROACH OF OBTAINING MEASUREMENTS OF VALLEY CROSS SECTIONS. INVESTIGATE THE POTENTIAL OF THE LASER ALTIMETER IN ITS APPLICATION TO AERIAL SURVEYING, AND THE POSSIBILITY OF DIRECT SURVEY FROM THE AIR WITHOUT GOING THROUGH THE STEREO-MODEL PLOTTING PROCESS.

PROGRESS AND RESULTS: By year end Draper Lab (CSDL) contract work on the aerial profiling of terrain (APT) instrument system had completed two of the planned three years of fabrication. Funds allotted to the contract in FY80 totaled $3.04 million; needed in FY81 to complete fabrication are $1.61 million. All work continues generally on schedule with no intolerable surprises. Assembly of the stable platform (3 gyros, 3 accelerometers, and internal electronics) part of the inertial measurement unit (IMU) was completed and run through a thermal test program under normal operating power. Mechanical, optical, and electronic assembly work on the laser tracker was completed. Agreement reached with Office of Aircraft Services (OAS) to make available a deHavilland Twin Otter aircraft exclusively for the APT system by May 1, 1981. R.A. Mills (GD, Denver) selected key USGS representative to coordinate with OAS and CSDL on contract work for aircraft modifications and design electrical/cooling systems to support airborne APT systems. Project continues under NMD leadership with Lowell Starr as USGS Contracting Officer's "Designated

Technical Officer."

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NR019 NUMERICAL SIMULATION

PROJECT TITLE: NUMERICAL SIMULATION OF HYDRODYNAMIC PROCESSES IN RIVERS, ESTUARIES, AND EMBAYMENTS

WRD PROJECT NO.: NR 69-019

LOCATION: Topical Research

PROJECT CHIEF: BALTZER, ROBERT A.

HEADQUARTERS OFFICE: RESTON, VA

PROBLEM: TECHNICAL SOLUTIONS TO THE PROBLEM OF INVESTIGATING AND MANAGING WASTE MOVEMENT AND DISPOSAL IN REGULATED RIVERS, ESTUARIES, AND EMBAYMENTS REQUIRE QUALITATIVE AND QUANTITATIVE ASSESSMENT OF THE INTERACTIONS BETWEEN WASTE CONSTITUENTS UNDERGOING DYNAMIC TRANSPORT. MATHEMATICAL, NUMERICAL, COMPUTER-SIMULATION MODELS OFFER ONE VERY POWERFUL SOLUTION. BECAUSE WATER IS BOTH THE VEHICLE BY WHICH THE WASTE CONSTITUENTS ARE TRANSPORTED AND THE MEDIA IN WHICH THE CONSTITUENT INTERACTIONS OCCUR, THE TEMPORAL AND SPATIAL VARIATIONS OF THE FLOW APPRECIABLY GOVERN THE INTERACTIONS BOTH QUALITATIVELY AND QUANTITATIVELY. DESIGN OF THE DESIRED SIMULATION MODELS DEPENDS IN LARGE MEASURE UPON ACCURATE MATHEMATICAL/NUMERICAL REPRESENTATION OF THE HYDRODYNAMICS OF THE TRANSIENT FLOW PROCESS.

OBJECTIVE: THE BROAD OBJECTIVES OF THIS STUDY ARE TO THOROUGHLY EXPLORE THE HYDRODYNAMICS OF ONE, TWO, AND THREE-SPACE DIMENSIONAL TRANSIENT FLOWS IN WATERWAYS AND WATERBODIES (INCLUDING THE TRANSPORT AND INTERACTION OF CONSTITUENTS), AND TO DEVELOP THE MATHEMATICAL/NUMERICAL TECHNIQUES WITH WHICH TO SIMULATE THESE PROCESSES. THE ULTIMATE GOAL IS TO PROVIDE THE HYDROLOGIST WITH A SIMULATION SYSTEM COMPRISED OF RATIONAL MATHEMATICAL/NUMERICAL MODELS WITH WHICH TO EVALUATE THE EFFECT OF PAST, PRESENT, AND PROJECTED CHANGES IN PROTOTYPE WATERBODY SYSTEMS.

APPROACH: MATHEMATICAL MODELS, COMPRISED OF SETS OF NONLINEAR, PARTIAL, DIFFERENTIAL EQUATIONS, ARE DERIVED REPRESENTING VARIOUS TRANSIENT FLOW CONDITIONS. NUMERICAL TECHNIQUES ARE DEVELOPED TO SIMULATE THE VARIOUS FLOW REGIMEN REPRESENTED BY THE MODELS. FIELD DATA GATHERED AT SPECIFIC FIELD SITES AND/OR HYPOTHETICAL DATA REFLECTING A PROJECTED CHANGE IS USED TO PROVIDE THE NECESSARY BOUNDARY-CONDITION INFORMATION AND DRIVING FUNCTION WITH WHICH TO PARTICULARIZE MODEL SOLUTION. THE SIMULATION PROCESSES ARE ACCOMPLISHED USING LARGE-CAPACITY, HIGH-SPEED DIGITAL COMPUTERS AND VIDEOGRAPHIC OUTPUT EQUIPMENT.

PROGRESS AND RESULTS: The detailed written documentation of the new, one-dimensional, branch-network, flow-simulation model was reviewed, revised, and returned to the editors for final publication (hopefully, in calendar year 1980). Extensive field data were gathered and processed in preparation for implementation of this model in the upper Potomac Estuary extending from Chain Bridge to Indian Head. These data were subsequently used and the model implemented and calibrated inconjunction with a colleague. Substantial effort was again directed to the evaluation and procurement of equipment,

instrumentation, and instrumentation systems for use in conjunction with the Potomac Estuary Study, and subsequently, to their subsequent installation, operation, and proper maintenance. Considerable time was devoted to Potomac Study data reduction and to devising means for handling the specialized data being obtained. Basic digital systems for translating three types of raw data from three classes of in situ recording instrumentation were developed. Training of Potomac Estuary project technicians and other personnel in proper procedures to be followed in the field and in care and maintenance of varous instrument systems was performed. Two invited lectures were presented at an ASCE sponsored short course conducted at Texas A&M University in May. Two papers were coauthored with colleagues and presented at a professional society meeting in August. Consultation services and (in some instances) direct assistance and training were provided to several districts in support of their respective surface-water modeling efforts.

COMPLETED REPORTS:

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NR052 MODELING PRINCIPLES

PROJECT TITLE: MODELING PRINCIPLES

WRD PROJECT NO.: NR 73-052

LOCATION: Topical Research

PROJECT CHIEF: BENNETT, JAMES P.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: THE DEVELOPMENT OF MODELS OF HYDROLOGIC SYSTEMS REQUIRES THE DESCRIPTION OF INDIVIDUAL PROCESSES IN MATHEMATICAL TERMS AND THE SOLUTION OF SETS OF COMPLEX EQUATIONS IN DIFFERENTIAL FORM. RESEARCH IS NEEDED ON APPLICATION OF MATHEMATICAL THEORY TO SYSTEMS MODELING.

OBJECTIVE: TO DEVELOP MATHEMATICAL DESCRIPTIONS OF FLOW AND WATER QUALITY PROCESSES THAT CAN BE LINKED TOGETHER TO FORM MODELS OF HYDROLOGIC SYSTEMS. TO DEVELOP MATHEMATICAL TECHNIQUES FOR EFFICIENT SOLUTION OF EQUATIONS ON DIGITAL COMPUTER. TO DEVELOP TECHNIQUES FOR STUDYING SENSITIVITY OF PARAMETERS.

APPROACH: THE APPROACH TO THE PROBLEM WILL BE BY THEORETICAL STUDY, MODEL DEVELOPMENT AND MODEL TESTING.

PROGRESS AND RESULTS: Spent one man-month on teaching and revising flow and transport courses. Calibrated "box type" sediment transport and deposition model for Potomac estuary from Chain Bridge to Quantico. Completed analysis of longitudinal variation of sediment transport in Potomac estuary for two major storms early in calendar year 1979.

COMPLETED REPORTS:

NR088 Potomac Estuary Studies

PROJECT TITLE: Potomac Estuary Studies

WRD PROJECT NO.: NR 77-088

LOCATION: Topical Research

PROJECT CHIEF: Bennett, James P.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: The Potomac Estuary is the tidal portion of the Potomac River from Chain Bridge near Washington, D C , to its mouth on the Chesapeake Bay. During extreme low flow, the upper part of the estuary will be used as a fresh water supply for Washington, D C , while its sewage treatment plant effluent and that of other nearby cities are disposed of further downstream. This and other health, aesthetic, and recreational considerations require studies of: (1) fresh water supply quantities; (2) sediment sources, transport, and sinks; (3) point and non-point sources, transport, and sinks of nutrients and heavy metals, and the reactions involving these substances; (4) key biological species; (5) effect of flow redistribution due to diversion for municipal use; and (6) flooding.

OBJECTIVE: Design, install, and operate a data collection network to provide time-series, boundary value data to implement, calibrate, and verify a 2-D flow simulation model. Determine the nature and distribution of modern sediment inputs from various sources and to evaluate the importance of shore erosion as a source of sediment. Program, calibrate, and verify two-dimensional sediment transport and bed-sediment composition and elevation accounting simulation models. Determine nitrogen, phosphate, and heavy metal budgets for the Potomac and provide geochemical input into an ecological model. Institute a long-term biomonitoring program of the fresh-to-salt transition zone also to provide input into an ecological model.

APPROACH: In-depth field reconnaissance to determine best segmentation for flow and other simulation models. Joint project field reconnaissance during critical low flow period to assess present extent of eutrophication, dissolved oxygen problems, nutrient, and heavy metals concentration. Install water level recorders and key current meter stations for flow and transport modeling. Obtain representative bottom suspended sediment samples, from modern sediment sources. Obtain similar samples from estuary bottom to interpret transport patterns. Construct rating curves for gaged inflows, conduct areal surveys for sources from ungaged inflows, and calibrate sediment transport model using synoptic surveys. Assemble flow, nutrient, and heavy metal data to construct simple budgets of these substances. Establish permanent water and sediment sampling stations to determine net flux of nutrients and metals across the sediment-water interface. Conduct sampling programs to define open water metabolism and benthic faunae in the fresh-to-saltwater transition zone.

PROGRESS AND RESULTS: Hosted and participated in a seminar on water quality of the tidal Potomac River. Began operation of transport

stations located at Alexandria, Quantico, and 301 Bridge. Completed 4 studies to calibrate transport stations. Installed a water-quality monitor at Piney Point, 3 weather stations, and 10 stage recorders. Completed 5 longitudinal water-quality profiles of the tidal Potomac. Conducted a pilot study of dissolved oxygen under low flow conditions. Completed 4 BOD-DO station calibrations. Performed a pilot study of transport and reaction properties of orthophosphate in the vicinity of the Blue Plains STP outfall. Operated recording velocity meters at two of the transport stations. Mapped the effluent plume of the Blue Plains STP. Performed an intensive study to document distribution and dynamics of nitrogen, phosphorus, carbon, and silica compounds along with sediment and phytoplankton near the Blue Plains STP. Developed chlorophyll-a measurement methodologies. Documented the seasonal distribution and dynamics of phytoplankton in the Potomac tidal river. A box model for salt transport was calibrated. Preliminary computer simulations of orthophosphate concentration were performed.Project will be divided into several components for 81 FY.

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NR096 Computational hydraulics

PROJECT TITLE: Computational hydraulics

WRD PROJECT NO.: NR 79-096

LOCATION: Topical Research

PROJECT CHIEF: Lai, Vincent C.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: (A) Because of rapid change in computer capability and computing milieu, and deep involvement of WRD in computer modeling of many practical water problems, many research hydrologists find little time for carefully appraising the fundamental and up-to-date numerical tools they should be using. (B) Use of improper numerical methods, deficient knowledge on error analyses, and inadequate handling of parameter identification, all lead to serious simulation errors or total information losses. (C) Relatively little work has been done previously for analyses of convergence, stability and error criteria; moreover, such work has been limited to simple, linear, and idealized flow problems far from the real world which is mostly non-linear, and complex.

OBJECTIVE: (A) To investigate, compare, or appraise various numerical approaches, methods, schemes, or techniques for hydraulic or hydrodynamic simulation, to explore or test newly introduced numerical methods for their adequacy and applicability in hydrologic projects, or to devise or develop new numerical approaches as tools for simulation modeling in hydrologic process. (B) To conduct studies on numerical stability, convergence, accuracy, efficiency, parameter identification, and sensitivity analyses associated with nonlinear schemes or models in computational hydraulics and water resources problems which are more complex but physically more realistic than linear ones.

APPROACH: (A) Review existing and explore newly developed numerical approaches, methods, schemes and techniques. Investigate, for given flow problems, the effect of simulation results due to change in numerical methods and schemes, and for fixed numerical methods or schemes that are due to change in application problems. Compare relative advantages of various methods from different viewpoints. (B) Review physical concepts of nonlinear effects in various flow problems, study the roles of nonlinear terms in partial differential equations, and investigate the effects of nonlinear terms in different numerical schemes. Develop numerical techniques to handle the nonlinear terms in flow simulation, and investigate convergence, stability, accuracy, sensitivity, etc. Derive guidelines for error criteria for some of the nonlinear problems.

PROGRESS AND RESULTS: Review and study have been made of some numerical approaches, schemes and techniques for hydrodynamic simulation and reports reflecting such studies have been written (BIB002, BIB006, REP002) or are in preparation (PLN001). A new numerical approach called "filter-scheme" method has been devised and

is now under test and development (REP003). A numerical technique to increase computational accuracy called "extrapolation procedure" is under investigation. A theoretical study and a series of numerical experiments on extrapolation procedures have been conducted which yielded rather interesting results (REP001); further development is underway. A few specific hydraulics problems were investigated using special techniques of computational hydraulics. They are urban storm sewer flows in coastal areas (BIB004) transient flows in Pheasant Branch (an extremely short reach), near Middleton, Wis. (BIB006), and others.

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NR104 Modeling of Hydrodynamic Systems

PROJECT TITLE: Simulation Modeling of Hydrodynamic Systems

WRD PROJECT NO.: NR 80-104

LOCATION: Topical Research

PROJECT CHIEF: Schaffranek, Raymond W.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: Managing water use in riverine and estuarine systems requires an understanding of the governing supply, circulation, mixing, and flushing processes. Qualitative and quantitative evaluation of the hydrodynamic and transport properties of such water bodies can be computed via mathematical/numerical simulation models. To accurately simulate both the temporal and spatial variations of the flow, which significantly define the transport processes, the simulation model must be capable of accounting for hydraulic and tide-induced fluctuations, water withdrawals, discharges, winds, nonuniform geometric configurations, and other manmade or natural factors.

OBJECTIVE: To investigate and develop various mathematical/numerical techniques with which to simulate the hydrodynamics of one-, two-, and three-space dimensional transient flows in various water bodies. The primary goal is to develop a simulation system, in support of efficient mathematical/numerical models, which will provide the capability to quantitatively evaluate water body flow-patterns so as to describe the transport of solutes.

APPROACH: The simulation processes are accomplished using large-capacity, high-speed digital computers and various supporting peripheral equipment. Mathematical models, constituting approximate numerical solutions to the governing nonlinear, partial, differential equations, are derived and developed to simulate the transient flow and transport processes. Data, collected at specific locations and/or hypothetically-imposed, are used to provide the required boundary-condition information with which to effect the numerical solution.

PROGRESS AND RESULTS: (1) Modified bathymetric processing system to accommodate UTM (metric) coordinates. (2) Compiled, edited, processed, and filled NOS bathymetric data of the upper (riverine) segment of the Potomac Estuary. (3) Developed methods and computer software for referencing and extracting cross-sectional profiles from areal bathymetric survey data. (4) Developed various 1-D and 2-D model schematizations of the upper segment of the Potomac Estuary from the NOS data. (5) Conducted initial development and testing of the 1-D flow model of the upper segment of the Potomac Estuary. (6) Compiled, processed, and filed Potomac Estuary boundary. (7) Modified branch-network model flow equations and finite-difference scheme for nonprismatic channels.

SR029 PHYSICAL MODELING

PROJECT TITLE: PHYSICAL MODELING OF HYDROLOGIC SYSTEMS

WRD PROJECT NO.: SR 73-029

LOCATION: SOUTHERN MISSISSIPPI

PROJECT CHIEF: SCHNEIDER, VERNE R.

HEADQUARTERS OFFICE: BAY ST. LOUIS, MS

PROBLEM: THE MOVEMENT OF WATER IN ALL SYSTEMS IS GOVERNED BY THE EQUATIONS OF MASS MOMENTUM, AND STATE. THERE IS A NEED TO DEVELOP SOLUTIONS OF THESE EQUATIONS.

OBJECTIVE: TO DEVELOP SOLUTIONS FOR EQUATIONS BASED ON A COMBINATION OF MATHEMATICAL MODELS, UTILIZING HYDRAULIC THEORY TO THE MAXIMUM EXTENT POSSIBLE, AND LABORATORY AND FIELD EXPERIMENTS TO DEFINE THE UNKNOWN COMPONENTS IN THE MODELS.

APPROACH: CONDUCT CONTROLLED EXPERIMENTS IN LARGE SCALE OPEN-CHANNEL, AND HYDRAULIC LABORATORY FOR CALIBRATION OF SURFACE-WATER MODELS AND FOR BASIC UNDERSTANDING OF HYDRAULIC PROCESSES PERTINENT TO MODELING.

PROGRESS AND RESULTS: The finite element flow model was used to compute velocity distribution and stage for four cases in the Congaree River flood plain and for the Big Wills Creek (AL) flood plain. A research program is underway to improve the finite element model based on this experience. Reports on the hypothetical Mackay Dam break, hydraulic design of bridges with risk analysis and dam break research studies have been completed and published. Data have been collected on flow in bends in the flood plain model. Data compilations have been completed for uniform grass and cleared encroachment data.

COMPLETED REPORTS:

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WR064 POLAR ICE REMOTE SENSING

PROJECT TITLE: POLAR ICE REMOTE SENSING

WRD PROJECT NO.: WR 70-064

LOCATION: ARCTIC OCEAN

PROJECT CHIEF: CAMPBELL, WILLIAM J.

HEADQUARTERS OFFICE: TACOMA, WA

PROBLEM: One of the fastest varying large-scale features on the earth's surface is sea ice. Theoretical studies show that the ice canopy in polar regions to be of major importance in (1) determining the global heat balance, and (2) determining the varpor flux of water into temperate regions. In order to test the developing numerical models of polar regions it is necessary to acquire sequential large-scale synoptic data over polar regions. Remote sensing especially in frequencies in the microwave range, appear to offer the best change of obtaining these data.

OBJECTIVE: As Principal Investigator for Sea Ice for NASA and the Space Craft Oceanography Center-NOAA, we will design polar remote sensing experiments using NASA and other agency remote sensing aircraft and satellites. Aircraft and satellite experiments will be coordinated with necessary ground truth networks for the remote sensing systems. The basic premise for these plans will be to develop the correct remote sensing means to acquire data that will be useful in testing numerical models of sea ice and glacier ice.

APPROACH: Overflights during the 1970, 71 and 72 experiments in AIDJEX under our direction have shown that the two methods that appear to be of greatest potential use in observing sea ice are passive microwave and SLAR. In the Main AIDJEX Experiment (spring 1975-spring 1976) passive microwave and SLAR, as well as other remote sensing data, were collected in the Beaufort Sea by NASA remote sensing aircraft during all seasons. At the same time surface truth measurements were taken and satellite microwave imagery obtained. A Polar Ice Studies (PIS) program has been initiated with NASA-Goddard Space Flight Center in which passive and active microwave data are being collected using the NASA CV 990 airborne laboratory over several targets in the Arctic region, including the Greenland ice cap. These data will be compared with imagery from the Electronically Scanning Microwave Radiometer (ESMR) from Nimbus-5 for interpretation. ESMR imagery will also be used by the Project in a study of pack ice in the Antarctic oceans. The Project will be involved in similar sea ice remote sensing experiments using aircraft and the forthcoming Nimbus-G and Seasat-A satellites which will carry both passing microwave (Scanning Multichannel Microwave Radiometer - SMMR) and active microwave (Synthetic Aperature Radar - SAR) systems. Dr. Campbell is a member of the design teams for (1) the Seasat SAR, (2) the Seasat-SMMR and (3) the Nimbus-g SMMR. These teams hold responsibility for designing the experiment plans, choosing target sites, developing algorithms for all operational modes, and validation of results.

PROGRESS AND RESULTS: Designed and participated in NASA flights and ground truth for the Seasat and Nimbus-7 validation experiments, and participated in Canadian aircraft and surface experiments for these satellite studies. As part of work with Conservation Division, prepared three volumes showing dynamics and morphology of sea ice in Bering, Chukchi, and Beaufort seas. Project chief served as chairman and member of NASA work group which published a report on the ice and climate experiment (ICEX) in December 1979. Developed a quasi steady-state model for sea ice; work initiated, with NASA, to combine this model with another developed in NASA, and obtained preliminary results.

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WR077 GLACIOLOGY

PROJECT TITLE: Glaciology--water, ice, and energy balance of snow and glaciers, and snow and ice physics

WRD PROJECT NO.: WR 57-077

LOCATION: Glaciers in AK, WA & Other States

PROJECT CHIEF: MEIER, MARK F.

HEADQUARTERS OFFICE: TACOMA, WA

PROBLEM: Much of the nation's streamflow and soil moisture recharge are provided by snowmelt, and snow can be measured and managed for hydrologic purposes. Yet snow is highly variable in space and time, and no method yet exists for synoptic monitoring of areal extent. Glaciers are sensitive indicators of climate trends, have significant regulating effects on streamflow, may produce outburst floods and other hazards, and are useful analogs to several important geophysical processes. Yet glacier heat and mass balances cannot be quantitatively related to meteorologic parameters, the flow and storage of water in ice is poorly understood, and the englacial and subglacial environment presents severe measurement difficulties.

OBJECTIVE: Develop methods for synoptic monitoring of snowcover, obtain understanding of how meteorological processes determine snow accumulation and melt, and develop improved techniques for predicting snow mass, distribution, and snowmelt runoff using conventional weather data. Determine how meteorological processes affected glacier mass balances, and how changes in mass balance affect glacier motion, glacier variations, and runoff from glaciers; use this knowledge and glacier variation data to construct climatic histories. Measure and develop an understanding of the physics of water flow through ice and at the ice/rock interface and determine how this affects glacier sliding. Understand why certain glaciers behave in anomalous) ways (surges, calving retreats) and use this knowledge to minimize economic hardship in dangerous glacier situations.

APPROACH: Investigate the feasibility of using satellites and other remote sensing techniques for the measurement of mountain snow (extent, thickness, mass, and liquid water content). By operating a high-mountain field data network, attempt to relate snow changes to meteorologic elements. Develop numerical models relating water storage as snow to meteorologic input and runoff/evaporation output. Relate glacier mass balance at a field station to meteorological elements, and long-term changes in balance to runoff and ice flow. Use the resulting understanding to analyze variations of other glaciers in terms of climate. Measure water pressure and flow in, within, and out from various levels in and under a glacier, relate water movement to thermodynamics, hydraulics, and rheology of the local ice environment, and relate water pressure and thickness to rate of glacier sliding. Obtain sufficient data to model and thus predict the behavior of a typical surging glacier and a typical asynchronously varying calving glacier. Monitor potentially dangerous glacier situations, and where appropriate collect data and model future behavior.

PROGRESS AND RESULTS: Data on terminus position, variations, and adjacent water depth have been compiled for all 52 calving glaciers in Alaska. The Columbia Glacier data set was extended throughout the glacier using a new computer program developed to produce an adjusted data set consistent with a two-dimensional continuity equation. A two dimensional, finite-element glacier model which includes sliding and deformational dynamics was developed. Using this, the lowest 14 kilometers of Columbia Glacier was run to steady state under the assumption of terminus calving matching ice velocity. Quantitative measurements of calving varianles on 12 major tidal glaciers in Alaska show that calving speed is directly proporational to water depth at the terminus. This law was incorporated in a numerical calving model based on mass continuity and an assumed future retracted profile. Use of the calving model to predict the future of Columbia Glacier indicates that the rate of retreat will accelerate during the next two or three years, that the annual discharge of icebergs will increase to a peak of about 8-11 cubic kilometers per year in the period 1982 to 1985, and that the glacier will have retreated about 8 kilometers by 1986. Aerial photographic observations of Mount St. Helens were begun on March 24, 1980. Frequent photo flights with large format, oblique-mounted cameras have documented changes in the mountain and the eruptions. The 3,000 exposures as of September 1980 have been the major USGS non-cartographic photo collection. The amount of ice and snow removed during the May 18 eruption of Mount St. Helens has been estimated as 0.1 cubic kilometer. The Shoestring Glacier was beheaded by the eruption, and this caused an immediate deceleration of flow throughout its length. Volcanic ash thickness of greater than 2 centimeters was found to reduce the rate of snow melt. Less than 1 centimeter of ash increases the melt.

NR012 ESTUARINE ECOLOGY

PROJECT TITLE: EFFECTS OF WATER QUALITY CHANGES ON ESTUARINE BIOTA

WRD PROJECT NO.: NR 64-012

LOCATION: Topical Research

PROJECT CHIEF: CORY, ROBERT L.

HEADQUARTERS OFFICE: Edgewater, MD

PROBLEM: TO UNDERSTAND THE EFFECTS OF MAN'S ACTIVITIES ON ECOLOGY OF ESTUARIES BY STUDYING THE BIOTA AND ITS RELATION TO NATURAL AND ALTERED ENVIRONMENTS.

OBJECTIVE: TO FURNISH BASELINE INFORMATION THAT WILL HAVE TRANSFER VALUE TO OTHER ESTUARIES.

APPROACH: Ecological studies at multiple stations and in local areas will be an integral part of larger multidisciplined studies. The benthic macroinvertebrates will be studied qualitatively and quantitatively. Estuarine metabolism will be estimated using daily records of dissolved 0(2), temperature, conductivity, and sunlight. Environmental measurements will be made using monitors at fixedl ocations and portable equipment at transient stations.

PROGRESS AND RESULTS: Processing of benthic macro-in-fauna from 330 stations from 8 transects on the Potomac River, Md. continues with about 50 samples remaining. Approximately 8,000 oligochaetes represented by over 20 species have been slide mounted and identified, a reference collection assembled and an additional 4,000 mounted to be I.D.'d. Twelve segments of the tidal Potomac and 4 in the tidal Anacostia have been sampled for macro-molluscs. The Asian clam, 5 species of Unionids (freshwater mussels) and 3 species of snails have been collected, weighed, measured and are being analyzed for their trace metal content. A 10th year ofw ater quality and solar radiation data is being collected and processed from the Rhode River, Maryland.

COMPLETED REPORTS:

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Cory, R.L., Dresler, P.V., 1980, Water Quality in Rhode River of Smithsonian Institution Pier Near Annapolis, Md., January 1976 through December 1978, NTIS No. 79-101, 53 p.

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NR027 PLANT GROWTH AND HYDROLOGY

PROJECT TITLE: BASIC RESEARCH CONCERNING PERIODIC PLANT GROWTH PHENOMENA AND HYDROLOGY

WRD PROJECT NO.: NR 66-027

LOCATION: Topical Research

PROJECT CHIEF: PHIPPS, RICHARD L.

HEADQUARTERS OFFICE: RESTON, VA

PROBLEM: Many plant growth phenomena are controlled in part by environmental conditions. Since water availability to plants seems to be the single most important factor limiting food production in the plant, relationships must exist between various hydrologic factors or conditions and various plant growth phenomena. Studies to date indicate that such relationships are quite complex and little understood. Such an understanding must be established before plants can be utilized to interpret hydrologic phenomena or before an assessment can be made regarding the long range impact of water management on natural vegetational resources.

OBJECTIVE: Basic research objectives include determination of relationships between various hydrologic parameters and periodic plant growth phenomena, plant distribution, and three-dimensional growth of trees. The ultimate objective is to utilize findings of the basic research to enable generation of estimates of hydrologic information from plant growth phenomena. A specific long-range objective is the temporal extension of discharge histories of ungaged streams in the eastern portion of the Nation. Short-range objectives, while aimed at solving local problems, are intended to contribute toward the long-range objective through methods development and establishment of a data base.

APPROACH: Data are collected of growth responses of many species in innumerable habitats to ascertain types of hydrologic information recorded in plant growth. Methods are devised whereby hydrologic information may be estimated from plant growth phenomena. The primary data base is composed of standardized growth indices developed from tree-ring chronologies. Other parameters of growth, such as anatomical anomalies and wood density, and more standardized ecological measurements are also utilized. Models describing calibrations between growth and hydrologic parameters are developed, and, after testing and verification, are used to reconstruct (estimate) hydrologic histories.

PROGRESS AND RESULTS: Preliminary results strongly suggest that effects of acid rainfall are contained in selected tree-ring data. Data from collections along the southern Hudson River in New York indicate strong response to acid rainfall in some species and little or no effect in other species. A potential is indicated for the use of tree-ring data to delimit the areal and temporal extent of the effects of acid rainfall. Other studies have indicated that considerable environmental information is contained in intra-annual anomalies seasonal variations not discernable from simple, classical width

measurements, and it has been shown that anatomical anomalies can be used to date flood events during the growth season to within 1-2 weeks.

COMPLETED REPORTS:

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Carter, Virginia and Baker, C.P., 1978, Map of roads and ditches of the Great Dismal Swamp, Virginia and North Carolina: U.S. Geol. Survey Open-File Map 78-86, 1 p.

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Puckett, L.J., 1979, Reconstruction of drought in Virginia: a dendroclimatic investigation (abs.): Virginia Jour. Sci., v. 30, p. 57, 1 p.

Phipps, R.L., 1979, Problems and potentials of dendroclimatology in Virginia (abs.): Virginia Jour. Sci., v. 30, p. 57, 1 p.

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NR029 VEGETATION AND HYDROLOGY

PROJECT TITLE: BASIC RESEARCH IN VEGETATION AND HYDROLOGY

WRD PROJECT NO.: NR 58-029

LOCATION: Topical Research

PROJECT CHIEF: SIGAFOOS, ROBERT S.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: AN UNDERSTANDING OF THE EFFECTS UPON PLANTS OF VARIATIONS IN AREAL HYDROLOGY AND THE EFFECTS OF THE IMPACT OF EROSION, DEPOSITION, AND FORCE OF FLOODS UPON PLANTS IS NECESSARY IN ANY EVALUATION OF THE ECOLOGICAL CHARACTERISTICS OF DRAINAGE BASINS. PLANTS ARE PART OF THE ECOLOGICAL ENVIRONMENT AND ANY CHANGE IN PLANT COVER WILL AFFECT REGIONAL HYDROLOGY. A FUNDAMENTAL PROBLEM IS TO DETERMINE THESE EFFECTS.

OBJECTIVE: To learn from plants the relationship between variations in the distribution of species and the variations in the physical and hydrologic environment. To obtain data to reconstruct hydrologic histories of areas by extending the record in time and creating records where none exists. To map the distribution of plant species in the vicinity and natural and man caused sources of environmental contaminants and to analyse plant parts for contaminants. To learn the effects of vegetation modification upon the hydrologic and physical environment.

APPROACH: DIFFERENCES IN FORM, AGE, AND DISTRIBUTION OF PLANTS ARE STUDIED IN AREAS AND RELATED TO DIFFERENT REGIMENS OF STREAM FLOW AND DIFFERENCES IN THE PHYSICAL AND HYDROLOGIC ENVIRONMENT. MAN'S USE OF THE LAND, PAST AND PRESENT, ARE RECORDED AND RELATED TO DIFFERENCES IN PLANT DISTRIBUTION AND DIFFERENCES IN MICROTOPOGRAPHY. THESE RELATIONSHIPS ARE MAPPED AND ANALYSED STATISTICALLY.

PROGRESS AND RESULTS: KY strip mine report is being reviewed. Natural history study of National Center is being assembled.

COMPLETED REPORTS:

Reed, J.C., Jr., Sigafoos, R.S., Fisher, G.W., 1980, The river and rocks, U.S. Geol. Survey Bull. 1471, 75 p.

NR090 Wetlands research

PROJECT TITLE: Remote sensing and ecological research in wetlands

WRD PROJECT NO.: NR 73-090

LOCATION: Topical Research

PROJECT CHIEF: Carter, Virginia P.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: Wetlands are poorly understood, hydrologically controlled environments. They are essential elements in estuarine, marine, lacustrine, and riverine productivity. Information on (1) wetland hydrologic variables and their relation to wetland vegetation, (2) wetland dynamics and boundary fluctuations, (3) short and long term temporal changes and, (4) other ecological aspects is needed to improve our understanding of these ecosystems and to aid in classification and mapping, wetland plants may serve as sensitive hydrologic indicators giving information on water (oxygen) stress, water quality parameters such as salinity, turbidity, pH, nutrients, or the presence of various pollutants, or frequency and duration of inundation.

OBJECTIVE: To relate the spectral characteristics of wetland vegetation andsurface moisture to interpretation of remotely-sensed data. To develop improved methodology for mapping and classifying coastal and inland wetlands in cooperation with other interested government agencies and non-government groups or individuals. To examine seasonal and long-term changes in wetland ecology as related to changes in environmental parameters including hydrology, water quality, and land use. To assist with interdisciplinary studies requiring biological research or remote sensing such as the Potomac Estuary Study. To aid in the development of models that utilize remote sensing or biological-hydrologic data as part of the prime data base.

APPROACH: Develop cooperative research projects, cooperators include WRD Districts, TVA, Topo Division (USGS), USFWS, NASA, JPL, interested State agencies and local groups, and others, work with all types of remotely-sensed data and available types of analysis equipment in order to achieve the best possible results in a variety of wetlands studies. Assist in interdisciplinary studies by providing biological and remote sensing information that can be related to study objectives.

PROGRESS AND RESULTS: (1) Third year of sampling submersed aquatic vegetation on the tidal Potomac has begun. Distribution and abundance are being correlated with water-quality data collected by the Potomac Estuary Study. (2) Study of environmental factors and control on SAV distribution initiated. (3) Preparation of booklet on SAV of Potomac River in progress. (4) Analysis of Landsat classification accuracy on Dismal Swamp complete. (5) Dismal Swamp transition zone project and vegetation-ground water study continue.

COMPLETED REPORTS:

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Morrow, J.W., and Carter, Virginia, 1978, Wetland Classification on the Alaskan North Slope: in Proceedings of the Fifth Canadian Symposium of Remote Sensing, August 28-31, 1978, p. 94-103, 10 p.

Gammon, Patricia, and Carter, Virginia, 1979, Vegetative mapping with seasonal color infrared photographs: Photogrammetric Engineering and Remote Sensing, vol. 45, no. 1, p. 87-97, 11 p.

Carter, Virginia, Bedlinger, M.S., Novitzki, R.P., and Wilen, W.O., 1979, Water Resources and Wetlands: in Wetland Functions and Values: the State of Our Understanding; Proceedings of National Symposium on Wetlands, Nov. 6-10, 1978, Lake Buena Vista, Florida, American Water Resources Association, p. 344-376

Mead, R.A., and Gammon, P.T., 1979, A practical and easily implemented method for mapping wetlands using small-format aerial photography: in 7th Bienn. Color Aerial Photography Workshop, Davis, CA, May 1979, Proc., p. 53-62

Haramis, G.M., Carter, Virginia, Gammon, Patricia, and Hupp, Cliff, 1979, Seasonal occurrence and distribution of submersed aquatic macrophytes in the tidal Potomac River: Seminar on Water Quality in the Tidal Potomac River, December 1978, U.S. Geol. Survey Open-file Report 79-1588, p. 19

Platts, W.S., Carter, Virginia, Janes, E.B., Terrell, T.T., and Theurer, F.D., 1980, An aquatic classification for integration into range planning and management (Abstract): in Abstracts and Position Statements, Society for Range Management 33rd Annual Meeting, San Diego, California, February 11-14, 1980, 1 p.

NR100 Dating Infrequent Floods

PROJECT TITLE: Botanical Dating of Infrequent Floods

WRD PROJECT NO.: NR 79-100

LOCATION: Topical Research

PROJECT CHIEF: Sigafoos, Robert A.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: Climate is continually changing and the need to predict future changes is critical. The problems are short-term records and lack of records of variations in climatic change that prevent reliable predictions.

OBJECTIVE: Many alluvial cones, debris fans, and channel deposits, the result of catastrophic floods, are present in the Appalachian Mountains and in the Cascade Mountains. Many of these areas support virgin forests, which, because of evidence from other studies, probably started to grow within a few years after the deposition of the land form. By determining the ages of many trees on many flood deposits in similar geologic environments, the dating of climatic-related events can be determined.

APPROACH: Shape, distribution, and age of plants growing on land forms created by catastrophic floods will be studied. Land forms will identify the existence of the event; distribution of the plants will show differences in the physical environment and the ages of trees will provide a minimum age of the deposit or flood.

PROGRESS AND RESULTS: One paper correlating high stream flow with block field movement is in final review and should be published in 1981. A paper extending the flood record of a low order stream is near completion. Data collection for study of the effects of low frequency floods on vegetation and flood plain sediments is also near completion. Results, to date, indicate a strong relation between type/growth form of vegetation and flood frequency magnitude.

NR101 Tree rings and Drought

PROJECT TITLE: Tree-ring reconstruction of drought severity in the Occoquan basin, Virginia

WRD PROJECT NO.: NR 79-101

LOCATION: Topical Research

PROJECT CHIEF: Phipps, Richard L.

HEADQUARTERS OFFICE: Reston, VA

PROBLEM: The Occoquan basin is the water source for a reservoir which supplies water to much of populous northern Virginia. Less than 40 years of streamflow records are available. This length record is not sufficient to allow determination of recurrence intervals of severe droughts.

OBJECTIVE: By the use of tree rings as proxy hydroclimate data sources, reconstruct mid to late summer drought conditions in the Occoquan basin for the last 250 or more years. Examine drought frequency and magnitude in the basin.

APPROACH: Develop a half dozen or more hydroclimatically sensitive tree-ring chronologies from the region; utilize multivariate statistics to determine limiting factors on tree-ring formation; calibrate tree rings with hydroclimatic factors; reconstruct hydroclimate factors from tree-ring data, and examine drought frequency and magnitude.

PROGRESS AND RESULTS: Models were constructed which describe the correlation between Occoquan streamflow and tree growth. The models permit the estimation of monthly streamflow from standardized tree-ring indices representing a minimum of 135 years. Streamflow reconstructions provide a 3-fold increase in record length, which should allow a more reliable estimate of the frequency with which extreme low flow occurs. Procedures to verify the models are in process, and a report to describe reconstruction results is in preparation.

WR012 Limnology: Aquatic Ecosystems

PROJECT TITLE: Limnology: Controls on biotic community distribution and composition, and microbial biogeochemistry of solute transformations, in aquatic environments

WRD PROJECT NO.: WR 61-012

LOCATION: Topical Research

PROJECT CHIEF: SLACK, KEITH V.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Aquatic biota both affect, and are affected by, their environment. Environmental change will result in a different biotic community. Better understanding is needed of mechanisms of biotic response to environmental alteration and of factors that affect composition and function of communities. Microorganisms alter the solute chemistry of aquatic environments. The complex biochemical and ecological mechanisms by which these processes proceed are poorly understood. These processes are important to water quality, geochemistry, and ecology. Measurements are needed of the rates at which these transformations occur in nature as is better understanding of the complex parameters which govern these rates.

OBJECTIVE: Determine relationship of chemical water quality and in-stream physical conditions (current, depth, sediment type, channel morphology, and light) to macro-, meso-, and microscale distribution and composition of aquatic communities of periphyton and benthic invertebrates. Determine interactions of these communities and their individual and combined response to environmental alteration. Measure in situ knetics of microbial transformations of important constituents (e.g., C, N, S). Understand these processes in terms of their rate limitations. Develop temporal transformation budgets for selected aquatic environments.

APPROACH: Research consists of three interrelated phases, (1) benthic invertebrate studies, (2) periphyton studies, and (3) microbial biogeochemistry of solute transformations. The phases differ in sampling methods, parameters, and experimental designs. The first two are conducted in streams of contrasting physical and chemical character. Differences in community structure and function are related to environmental differences using multivariate analysis. Field results are tested in laboratory and field experiments in which functional interactions are identified and quantified. The third phase uses laboratory and in situ cultures of bacteria to study generation and alteration of geochemically significant compounds in freshwater, estuarine, and marine environments. Products are identified and rate limiting factors determined using gas chromatography, optical emission spectroscopy and other advanced analytical instrumentation.

PROGRESS AND RESULTS: Designed new artifical substrate device to improve benthic invertebrate sampling in rocky streams. The new sampler flushes slowly and accumulates detritus and inorganic

sediment. When exposed for 41 days in stream ranging from order 2 to order 7, the new samplers collected nearly twice as many taxa and eight times as many individuals as Hester-Dendy multiple plate samplers. Identified possible precursor molecules and responsible microbes for ethene and enthane formation. Demonstrated anaerobic oxidation of acetylene. Measured dissolved metabolic gases in response to a sewage spill and recovery in San Francisco Bay.

COMPLETED REPORTS:

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Oremland, R.S., 1979, A mechanism for in Situ biological formation of methane in oceanic surface waters (abstract): Trans, AGU (EOS), v. 59, p. 1097,

Tilley, L.J., 1980, Family Chironomidae (Diptera): Quality of Water Branch Technical Memorandum No. 80-08. February 21, 1980, 9 p.

Taylor, B.F., and Oremland, R.S., 1979, Depletion of adenosine triphosphate in Desulfovibrio by oxyanions of Group VI elements: Current Microbiology, v. 3, p. 101-103, 3 p.

Oremland, R.S., 1979, CH(4) content of geothermal gases before and after an earthquake: Abstract, EOS Trans. Am. Geophys. Union, v. 80, p. 883, 1 p.

Oremland, R.S., Culbertson, C., and Kvenvolden, K.A., 1980, Microbial formation of ethylene and ethane in anoxic estuarine sediments: Abstract, Ann. Meeting, Am. Soc. Microbiology, 1980, #I 118, Miami, Florida, 1 p.

WR068 Fate of Organics in Groundwater

PROJECT TITLE: Fate of Organic Chemicals in Subsurface Environments

WRD PROJECT NO.: WR 71-068

LOCATION: Topical Research

PROJECT CHIEF: EHRLICH, GARRY G.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Uncontrolled release of synthetic organic compounds to the environment has caused many soil and groundwater pollution problems. The factors which determine their persistence and rates of transport in subsurface environments are not well understood. An understanding of the factors which control the fates of these materials is necessary for construction of mathematical models to predict their movement and to develop clean-up schemes.

OBJECTIVE: To determine the courses and rates of chemical transformations of certain organic compounds under conditions simulating various subsurface environments. To assess the relative importance of physical, chemical and biochemical processes to the ultimate fate of these compounds. To determine the characteristics of microbial communities responsible for in-place biotransformation of selected organic substances.

APPROACH: (1) Naphthalene and pentachlorophenol (PCP) have been selected as the initial study target compounds. The sorption of naphthalene and PCP on glass beads, loam soils, and aggregated soils will be determined. (2) Pure and mixed cultures of naphthalene and PCP degraders will be obtained and characterized.(3) Chemical and biochemical transformaion of naphthalene and PCP in soil columns will be studied under dynamic flow conditions.

PROGRESS AND RESULTS: Naphthalene-and pentachlorophenol (PCP)-degrading bacteria were isolated from creosote-PCP contaminated ground water at Visalia, CA and St. Louis Park, MN. Kinetics of mixed-culture microbial naphthalene-PCP degradation in stirred, aerobic, liquid phase reactors were studied. HPLC procedures for determination of naphthalene, pentachlorophenol and Krebs cycle intermediates were developed and used to support biodegradation studies.

COMPLETED REPORTS:

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WR125 TRACE ELEMENT AVAILABILITY IN SEDIMENTS

PROJECT TITLE: AVAILABILITY OF TRACE ELEMENTS IN SEDIMENTS TO MACRO-INVERTABRATES

WRD PROJECT NO.: WR 75-125

LOCATION: Topical

PROJECT CHIEF: Luoma, Samuel N.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: The concentration of potentially toxic elements in sediments is generally orders of magnitude greater than the concentration in waters with which the sediments are in contact. Inadequate information is available on availability to detritus feeding organisms of trace elements in suspended or bed sediments, or the effect of high sedimentary trace element levels on detritus feeders and their food web.

OBJECTIVE: (1) Determine influence of the geochemical characteristics of sediments on metal concentrations observed in detritus feeding invertebrates. (2) Assess chemical methods for predicting the biologically available fraction of metals in sediments. (3) Determine the relative contribution of sedimentary and solute metal forms to concentrations observed in detritus feeders. (4) Determine the concentration of biologically available trace elements at which biological effects occur in detritus feeding species.

APPROACH: Collect detritus feeders and surface sediments from various estuarine and marine microhabitats. Analyze animals for metals. Extract sediments with reagents previously shown useful in chemically characterizing sediments and with potential for predicting the biologically available metal fraction in the sediments. Assess the relative importance of sedimentary and solute metals directly by use of field experiments with transplanted animals and indirectly by studying metal distributions in populations as a function of size. Determine the presence of biological effects by determining tolerance of organisms to toxic metals, and look for levels of biologically available metals at which such tolerances appear.

PROGRESS AND RESULTS: (1) A comprehensive report summarizing 5 years of study on the bioavailability of trace metals was prepared and published; (2) Studies were begun on the differences in response to trace metals of different populations of clams; (3) A conceptual model was developed, from a synthesis of 3 years of data in San Francisco Bay, explaining why a variety of correlations between animal size and metal concentrations may occur in nature. Such understanding is essential to interpreting metal concentrations in organisms; (4) 14 reviews of the impact of waste-water discharge on San Francisco Bay were begun; (5) Assistance (lab analysis, data interpretation, study design) was given Nevada and Wyoming Districts in trace-metal studies; and (6) An ongoing sampling program was continued at 5 stations in San Francisco Bay.

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Luoma, S.N. and Bryan, G.W., Trace metal bioavailability: Modeling chemical and biological interactions of sediment-bound Zn, in chemical modeling-Speciation, sorption, solubility and Kinetics in aqueous systems, American Chemical Society, p. 577-611, 34 p.

Luoma, S.N. and Bryan, G.W., Factors controlling the bioavailability of sediment-bound lead to an estuarine bivalve: Journal Marine Biological Association, United Kingdom, 48, 793-801. 8 p.

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Luoma, S.N., and Cain, D.J., 1979, Fluctuations of copper, silver and zinc in tellenid clams as related to Freshwater discharge -- South San Francisco Bay, in: San Francisco Bay: The Urban Estuary, American Association for Advancement of Science, p. 231-246, 32 p.

WR137 Toxic Substances: Aquatic Ecosytems

PROJECT TITLE: Effects of Toxic Substances Related to Expanding Energy Technologies on Aquatic Ecosystems

WRD PROJECT NO.: WR 75-137

LOCATION: Nationwide

PROJECT CHIEF: Leland, Harry V.

HEADQUARTERS OFFICE: Menlo Park, CA

PROBLEM: Anticipated increases in fossil fuel extraction and consumption and the rapid development of other energy sources (e.g., geothermal) are of major environmental concern. The ecological effects on surface waters of wastes from fuel combustion and of toxic materials from fuel extraction are of particular concern. Standard methods for evaluating effects of toxic substances at sub-lethal levels in aquatic ecosystems are not available. There are several promising but untested methods to determine responses of individual species which are of potential value in monitoring programs. Data from the field and from laboratory streams, on effects of continued low levels of toxicants on function and structure of aquatic ecosystems, are almost wholly lacking.

OBJECTIVE: To determine through detailed studies of organisms, simplified ecosystems and natural sites the extent to which trace metals and stable organic compounds of fossil-fuel origin affect the production and structure of aquatic plant assemblages and the growth and reproductive capacity of aquatic animals. To evaluate methods of assessing effects of chronic exposures of toxicants on individual species and natural aquatic communities.

APPROACH: Evaluate methods for assessing effects of chronic exposures of toxic substances released to the environment as a consequence of fossil fuel extraction and combustion. These include tests of hatchability, embryogenesis and respiratory response in fishes, specific birth rate and survival of critical life stages of aquatic invertebrates, and population growth rate of algae. Determine physico-chemical factors affecting responses and bioaccumulation of these toxic substances. Examine trophic dynamics of simplified aquatic ecosystems (experimental streams) exposed to chronic exposures of trace metals and stable organic compounds of fossil fuel origin. Evaluate methods and results of laboratory and experimental stream studies by field experiments. Determine the utility of the biological test methods for detecting and monitoring small concentrations of toxicants. Examine the variables (physico-chemical and biological) influencing responses of natural aquatic communities.

PROGRESS AND RESULTS: Changes in community function and structure of Aufwuchs in a pristine stream during continuous, low-level exposure to copper were determined. Inhibition of photosynthetic carbon fixation and sulfate assimilation was observed within the first 48 hours at 7 and 15 ug Cu/liter, but not at 2.5 ug Cu/liter. Additional effects observed during long-term continuous exposure to the two

higher copper concentrations were reductions in standing crop (chlorophyll a and ash-free dry weight) rate of colonization, rate of nitrogen fixations, rate of microbial decomposition of leaf litter, algal species diversity and microfaunal (ciliated Protozoa and Rotifera) species diversity. Field work on all phases of the study of community responses to copper (Aufwuchs, benthic insects and fishes) was completed.

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Oremland, R.S. and Taylor, B.F., 1978, Sulfate reduction and methanogenesis in marine sediments: Geochim. Cosmochim Acta, v. 42, pp. 209-214.

Capone, D.G., Oremland, R.S., and Taylor, B.F., 1978, Significance of N(2)-fixation to the production of Thalassia testudinum communities," in CICAR II: Symp. Progres Mar. Res. Caribb Adj. Regions, H.B. Stewart, Jr. (ed.) FAO, Rome, pp. 71-86.

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WR145 Vegetation ecohydrology

PROJECT TITLE: Ecohydrology of arid region vegetation

WRD PROJECT NO.: WR 76-145

LOCATION: Arizona, arid regions

PROJECT CHIEF: Turner, Raymond M.

HEADQUARTERS OFFICE: Tuscon, AZ

PROBLEM: Water is becoming increasingly scarce in the arid region of the United States. In his attempt to manage or control this essential resource, man is constantly modifying the regional hydrology by changing water-table elevations, altering surface drainage patterns, controlling streamflow, and altering erosion. These and other modifications may result in altered water quality and often result indirectly in vegetation changes that reflect the changed regional hydrology. Man also changes the vegetation directly through agricultural practices, urbanization, vegetation management activities, all of which have an impact on the region's hydrology.

OBJECTIVE: To define the interrelationship between the region's hydrology and its vegetation. To measure the effect that the changing patterns of vegetation have on the regional water supply and, conversely, the effect that changes in water quality and quantity have on the vegetation.

APPROACH: Use historical documents and old photographs to determine the scope of vegetation changes. Use remote sensing products such as aerial photographs and satellite images to locate, map, and measure existing vegetation. Riparian and phreatic vegetation will be emphasized because, compared to the area they occupy, their hydrologic and ecological significance is disproportionately great. The communities are valuable wildlife habitats and recreation sites; at the same time they consume and transpire large amounts of water. Studies of desert plant populations will be made because vegetation changes at dry sites may be sensitive indicators of large scale climatic change.

PROGRESS AND RESULTS: Initiated study of rainfall versus ephemeral desert plant establishment. Continued analysis of channel and vegetation changes along Arizona rivers with the current emphasis on the San Pedro and Santa Cruz Rivers. Completed analysis relating temperature and rainfall parameters to weekly growth in the saguaro. Completed study of revegetation of abandoned croplands.

COMPLETED REPORTS:

Brown, D.C., Carmony, N.B., and Turner, R.M., compilers, 1978, Drainage map of Arizona showing perennial streams and some important wetlands: (Contains selected references and annotation by N.B. Carmony), 2nd edition, Arizona Game and Fish Dept., 1 sheet (both sides).

Park, D.M., Culler, R.C., and Turner, R.M., 1978, Management of flood-plain vegetation, 1967 to 1972, San Carlos Indian Reservation: U.S. Geol. Survey Open-File Report 78-412, 21 p.

Turner, R.M., Applegate, L.H., Bergthold, P.M. Gallizioli, Steve, and Martin, S.C., 1979, Range references areas in Arizona (ABSTRACT ONLY): Arizona-Nevada Academy Science Journal, v. 14, 1979 Proceedings Supplement, p. 50-51, 1 p.

van Hylckama, T.E.A., 1979, Changes in vegetation diversity caused by artificial recharge: Vegetation, v. 39, no. 1, p. 53-57, 5 p.

Turner, R.M., and Karpiscak, M.M., 1980, Recent vegetation changes along the Colorado River between Glen Canyon Dam and Lake Mead, Arizona: U.S. Geol. Survey Prof. Paper 1132, 125 p.

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WD031 SYSTEMS ANALYSIS LAB

PROJECT TITLE: HYDROLOGIC SYSTEMS LABORATORY GROUP

WRD PROJECT NO.: WD 68-031

LOCATION: administrative

PROJECT CHIEF: James, Ivan C., III

HEADQUARTERS OFFICE: RESTON, VA

PROBLEM: New national problems are emerging for which the synthesis and presentation of appropriate water resources information are underdeveloped. The data collection and interpretative programs of the Division must maintain relevance to these changing needs of planning and design of water-related facilities and policy decision making that affect the supplies, demands, and quality of the water resources.

OBJECTIVE: To develop concepts and analytical techniques for designing data collection systems and interpretative procedures responsive to the needs of water resources systems planning and management.

APPROACH: Models of decision-making processes, that is, planning, design, and management, are developed and tested for sensitivity to the amounts and types of hydrologic information utilized in them. These results provide a basis for optimal allocation of data collection and interpretative program resources. New procedures are developed for incorporating water resources information with economic and environmental information for direct use in the policy-making process.

PROGRESS AND RESULTS: (1) Water use in energy production and conversion - Coal mining, SYNTHANE gasification, and coal-fired electric power generation were investigated for water use, residuals generation, and costs using four types of cooling systems and under two levels of residuals modification. Detailed material and energy balance calculations were performed and later coded into computer programs for the SYNTHANE process. These programs provide the design information that is used in equipment costing and siting, calculations which have been programed. Even though some water is used consumptively in chemically providing the hydrogen for coal gasification, electric power generation is a more intensive water user because of its higher cooling requirements. Either mechanized draft or natural draft wet cooling towers are high in water consumption followed by cooling ponds and lastly by once-through cooling. Tradeoffs between water use, capital costs, and energy efficiency have been defined for these four cooling systems. Throughout much of the intermountain West, land of suitable slope for large cooling ponds does not exist, and large enough quantities of flow are not naturally available for once-through cooling without biologically unsound increases in stream temperature. Water use in mining and reclamation is small relative to water use in any of the conversion technologies. Material and energy balance calculations have been performed for the

SYNTHOIL liquifaction process and preliminary water use estimations made. (2) Oilspill risk analysis - A model for stochastically generating oilspills and performing trajectory analyses of the spills from outer continental shelf oil lease areas was constructed for the Northern Gulf of Alaska lease area. Since then, analyses have been completed for the Mid-Atlantic, North Atlantic, and South Atlantic lease areas. The analysis for the Kodiak lease area is now in progress. In general, it was found that the average time to beaching of a spill is in the order of a month. The probability of a spill beaching from a particular site is somewhat higher in summer than winter, with the probabilities for spring and fall somewhat in between. A majority of production spills from the South Atlantic lease area will beach while only a minority of those from the Mid-Atlantic and North Atlantic lease areas will beach. Transportation-related spills will beach with a higher probability than production spills because of their increased proximity to shore. (3) Flood frequency analysis - Continuing research (with J. R. Wallis, IBM Research Center, Yorktown Heights, N.Y.) has substantiated earlier results indicating that knowing the underlying distribution of floods is of no economic gain. Use of the normal distribution to approximate the distribution of floods is quite robust over a wide range of assumed flood frequency distributions. Efforts to define regional skews are likely to prove more difficult than previously imagined in light of the fact that to explain certain statistical properties of the skew statistic might require assumptions of nonstationarity if skews are small, whereas high skews might allow the assumption of stationarity but increases the sampling error. Reductions in expected design losses would only be marginal for improvements in the estimates of the mean and skew without improvements in the estimates of the variance.

W R D F e d e r a l R e s e a r c h P r o j e c t s

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