OTT WATER ENGINEERS

ENGINEERS • PLANNERS • SCIENTISTS

SUSITNA HYDROELECTRIC PROJECT

Streamflow Forecasting Feasibility Study

Prepared for:

Harza-Ebasco Susitna Joint Venture
Anchorage, Alaska

Prepared by:

OTT WATER ENGINEERS, INC.
4790 Business Park Blvd.
Building D, Suite 1
Anchorage, Alaska 99503

October, 1984

A456.00

TABLE OF CONTENTS

SECTION 1

OTT WATER ENGINEERS
4790 Business Park Boulevard, Bldg. D, Suite 1 Anchorage, AK 99503 907/562-2514

September 28, 1984

Harza-Ebasco
Susitna Joint Venture
711 "H" Street
Anchorage, Alaska 99501

ATTN: Mr. W.E. Larson

SUBJECT: Proposal for Susitna Hydroelectric Project Streamflow Forecasting Feasibility Study.

Attached are 5 copies of the Ott Water Engineers, Inc. (OTT) proposal for the Streamflow Forecasting Feasibility Study.

OTT has assembled an extremely qualified, highly experienced project team. Our team members have worked together in many hydrologic instrumentation and modeling studies throughout Alaska and the United States. OTT offers a full range of hydrologic capabilities. We have extensive Alaskan experience in the design, installation, operation, and maintenance of large hydrological monitoring networks, and in computerized data reduction and analysis. We maintain a large repertoire of computer models.

Our corporate commitment to this project is demonstrated by the fact that our five-man project team is composed of four OTT principals, Dave Black, John Humphrey, Dennis Dorratcague, and Ron Ott, corporate president and senior consultant of the firm.

Dave Black will serve as the Project Manager. All OTT's managers, including the Regional Manager, are "working managers" who spend up to 50 percent of their time on active client projects. Our high level managers are expected to manage projects, perform technical work, and provide technical direction. In this way we can produce a high quality technical product and reduce OTT's internal management overhead, thereby reducing client costs.

If you have any questions or need additional information please contact me. Thank you for the opportunity to submit this proposal.

Sincerely,

OTT WATER ENGINEERS, INC.

William L. Ryan
Regional Manager

SECTION 2

2. EXECUTIVE SUMMARY

The Susitna Hydroelectric Project is being designed to provide a stable, economic, electrical energy source for the Alaska Railbelt well into the 21st century. This enterprise has raised numerous concerns within public and private sectors regarding potential impacts to the seasonal discharges of the Susitna River system, its aquatic habitat, and fishery resources. The Alaska Power Authority (APA) desires to minimize the differences between the potentially conflicting demands of reservoir operations for power production versus maintenance of instream flow requirements for the fishery resources. In fact, APA is considering various project flow regimes and operational scenarios intended to optimize power production, insure project safety, and minimize deleterious fishery impacts. To meet these goals, it is necessary to evaluate each operational scenario objectively via analytical modeling techniques. However, to achieve significant results, the modeling effort must be coupled with a reliable, short-term and long-term streamflow forecasting methodology. In addition, the methodology should provide the most cost effective balance between data collection and operational expenses versus predictive accuracy and reliability. The primary objective of this project is to provide APA with detailed information and recommendations to aid their identification of priorities and selection of the system to be implemented.

OTT proposes to fulfill these objectives based on the seven task work plan summarized below.

Task 1: Determine data and operational requirements and costs of existing methodologies.

Task 2: Evaluate the output capability of available models.

Task 3: Establish a selection criteria matrix to prioritize methodologies.

Task 4: Determine hardware and software requirements and cost.

Task 5: Evaluate data availability and data acquisition costs to meet model requirements.

Task 6: Recommend those models and field programs that are able to achieve project requirements.

Task 7: Report

Descriptions of each task are provided in the Scope of Work section within this proposal. Basically, the evaluation of operational costs and output reliability and suitability to APA will be addressed via an in-depth library research effort. Existing technical reports will be evaluated to determine the data network size, modeling cost, and output accuracy. To be significant to this project, the cost of the monitoring network used in each report evaluated will be determined based on the installation and operational expense of a similar sized network within the Susitna River basin. Model output accuracy will be addressed by comparing the future predictions within each evaluated report to actual conditions that occurred after the report was published. In this manner, we will be able to provide APA with comparisons between differing methodologies based on actual operational histories. Additionally, each individual methodology will be evaluated for its output accuracy versus monitoring network density and duration so that an optimal system may be selected.

OTT's modeling experience is evidenced by the fact that we have successfully completed over 500 hydrologic and hydraulic precipitation-runoff projects throughout the western United States and Alaska. Moreover, we have recently completed two state of the art studies concerning glacial hydrology processes in Alaska. We offer a complete range of hydrologic services including design, installation, operation, and maintenance of large hydrological monitoring networks; and computerized data reduction and analysis. We maintain a large repertoire of computer models on line.

Our experience indicates that the major limitation of the recently introduced, sophisticated models is their data base requirements. In order to realize increased output precision, these models require extensive data input in terms

of the number of required monitoring stations and length of record. Without sufficient field stations with relatively long periods of record, the advanced models must rely on default values when data requirements are not met; the use of default values severely limits the predictive accuracy of these advanced techniques. The most severe limitation, however, is not the costs of increased monitoring sites but the minimum monitoring time that is required. Few projects can afford the delay created by collecting 5 to 10 years of data before calibration and verification of model output can begin. It is likely that project schedule delays for increased data collection will be unacceptable to APA. Therefore, it is apparent that field data collection expertise is as important to this project as modeling proficiency.

OTT has extensive experience in the design, installation, operation and data analysis of hydrological and meteorological networks throughout Alaska and the western United States. In fact, we are acknowledged as being the most experienced Alaskan firm with in-house expertise utilizing both mechanical and solid state monitoring devices. We have monitored Alaskan stream systems ranging from small basins to larger watersheds such as the Beluga, Tanana, Chulitna, and Eklutna River basins. In all cases, our field instrumentation has achieved nearly 100 percent data capture in spite of severe cold (-35°F), difficult access, and weather related servicing delays. As a result of these successes, we are currently upgrading our field instrumentation from standard mechanical devices to solid state digital recorders. OTT maintains the capability to electronically read, transmit, process, and analyze the digitized data base via computer, attaining the result of in-depth, low cost, high precision data analysis. Our field expertise coupled with our modeling experience insures a complete, detailed system analysis from field to final product.

SECTION 3

3. EXPERIENCE AND QUALIFICATIONS

Ott Water Engineers, Inc. (OTT) was established in 1978 as a team of five experienced water resources engineers. Since then, the firm has expanded to a staff of 40 engineers, scientists, and planners.

The Anchorage office was established in 1979 to provide engineering design and technical support services throughout Alaska. OTT specializes in water resources studies, data collection, and water project design.

For the Streamflow Forecasting Feasibility Study, OTT has assembled a team of its senior hydrologists and engineers to conduct and coordinate the work effort with the appropriate teams involved in the Susitna Hydroelectric Project. The OTT team is highly experienced in the application of numerous hydrologic modeling techniques. A description of some of OTT's computer modeling capabilities is provided in this section of the proposal.

HYDROLOGIC MODELING EXPERIENCE

HYDROLOGIC DESIGN MEMORANDUM
HUMBOLDT RIVER BASIN, NEVADA

For the U.S. Army Corps of Engineers (COE), OTT team members provided flood forecasting and reservoir storage modeling of three proposed dam sites on the Humboldt River. The drainage basin studied encompasses 16,000 square miles of watershed with critical water supply conditions. The COE model HEC-1 was modified to incorporate snowmelt and runoff relationships. Detailed analyses of these dam sites included the preparation of peak volume and frequency curves, flood hydrographs, standard project floods, and project maximum flood magnitudes for the Humboldt River system and its tributaries. The model was calibrated for the entire basin to simulate winter, spring snowmelt, and cloud burst flooding conditions.

WISCONSIN RIVER MODEL
WISCONSIN RIVER, WISCONSIN

The Stanford Watershed Model (SWM) with snowmelt routines was used to model the entire 2,000-square-mile upper Wisconsin River basin. This model was developed for use by the Wisconsin Valley Improvement Company to schedule storage and discharge operations of 15 dams. Twenty years of hydrological and meteorological records were used for calibration of snowmelt and runoff prediction.

WATER RESOURCES STUDY OF THE TRUCKEE RIVER BASIN
CALIFORNIA AND NEVADA

An extensive streamflow routing and reservoir operations model was developed to determine domestic, municipal, and industrial water supply sources and demands within the river basin. This model included snowmelt runoff forecasting and operational diversions from Lake Tahoe and 10 other alpine reservoirs. The model also effectively dealt with a complex series of municipal water supply demands, power and agricultural diversions, and minimum

streamflow requirements for fisheries. Water supply conditions were predicted for a 50-year period.

PUGET SOUND WATER RESOURCES STUDY
WASHINGTON

The snowmelt version of the Stanford Watershed Model was used to synthesize runoff records for a 100-square-mile watershed. Forty years of regional daily flow records were input to provide operational forecasting capability to the City of Seattle Water Department. The model also used hourly time steps of meteorological data to predict snowmelt and precipitation runoff.

GLACIER RUNOFF MODELING
ALASKA

Analyses of selected glacial basins were performed to supplement expert testimony during litigation. Synthesis of flood events was done for the Gulkana, Wolverine, Nuka, Mendenhall, Hubert, and Lemon Creek glacial basins using the snowmelt version of the HEC-1 model. The model was capable of simulating the attenuation and delay of runoff due to glacial influences.

HYDROLOGIC ANALYSES FOR HYDROPOWER
PACIFIC NORTHWEST

OTT applied various modeling techniques to simulate the period and duration of streamflows for numerous hydroelectric projects throughout the Northwest. Long-term daily flow records were compiled and correlated to simulate project site conditions. Synthesized annual hydrographs and exceedence curves were produced to evaluate power potential and bypass flow releases. Modeling also incorporated scenarios of intrabasin transfer, spring fed accretion flows, and snow pack prediction.

ADDITIONAL WATER RESOURCES INVESTIGATIONS

208 WATER QUALITY MANAGEMENT STUDY
ANCHORAGE, ALASKA

For the Municipality of Anchorage, OTT collected and analyzed all water data, described areas that had water quality problems, modelled impacts on streams and lakes from pollution sources, formulated alternatives to mitigate pollution problems, made presentations at public involvement meetings, and developed a 208 plan.

WATER RESOURCE MANAGEMENT STUDY
SEATTLE, WASHINGTON

For the City of Seattle and Metro, OTT performed studies on the Cedar and Green River basins that involved collecting data on water quantity and quality, and fisheries. The data was summarized and analyzed to determine the relationship between water quality and impacts on the fisheries in the Cedar and Green Rivers. Computer models were built to extrapolate this data into the future for changes in the land use and point sources of pollution. The study developed comprehensive water resource management plans for the Cedar and Green River systems.

STOCKTON SHIP CANAL STUDY
STOCKTON, CALIFORNIA

OTT performed a study for the City of Stockton that required gathering hydrodynamic water quality and meteorological data during two intensive sampling periods. This data was used to calibrate hydrodynamic and water quality computer models. The models were then used to predict the effect on the ship canal of the discharge of advanced waste treatment plant effluent.

208 WATER QUALITY MANAGEMENT STUDIES
DENVER, COLORADO

For the Denver Regional Council of Governments, OTT reviewed, analyzed, and developed an inventory of existing water quality and waste source data. A computer model was applied to simulate complex water quality interactions in the metropolitan portion of the five-county study area. Alternative structural and nonstructural control systems were developed and tested by computer simulation for both point and nonpoint waste sources.

WATER QUALITY MANAGEMENT STUDY
ST. LOUIS, MISSOURI

For the East-West Gateway Coordinating Council, OTT performed water investigations to determine impacts of hundreds of municipal and industrial waste sources and urban and agricultural nonpoint sources of pollution. Water quality models were applied to streams and rivers in the area. Management plans were evaluated and presented in public workshops.

SHASTA DAM MODEL OPERATION AND FLOOD STUDY
TEHAMA COUNTY, CALIFORNIA

OTT built a mathematical model of Shasta Dam to investigate floods in Red Bluff which could have been controlled by Shasta Dam before 1945. This study included a detailed review of Shasta Dam's operational policy since its construction. Local inflow between Shasta Dam and Red Bluff was quantified for the last 76 years. The model was then operated to produce a 76-year flood record for the Sacramento River at Red Bluff as if the dam had been in place the full time. The results of this study identified the 100-year flood flow at Red Bluff, which was used by the County in their flood insurance study.

URBAN STORMWATER AND COMBINED SEWER OVERFLOW
MILWAUKEE, WISCONSIN

For the Milwaukee Pollution Abatement Office, OTT determined the storm of record and the size of the collection and storage system that would contain

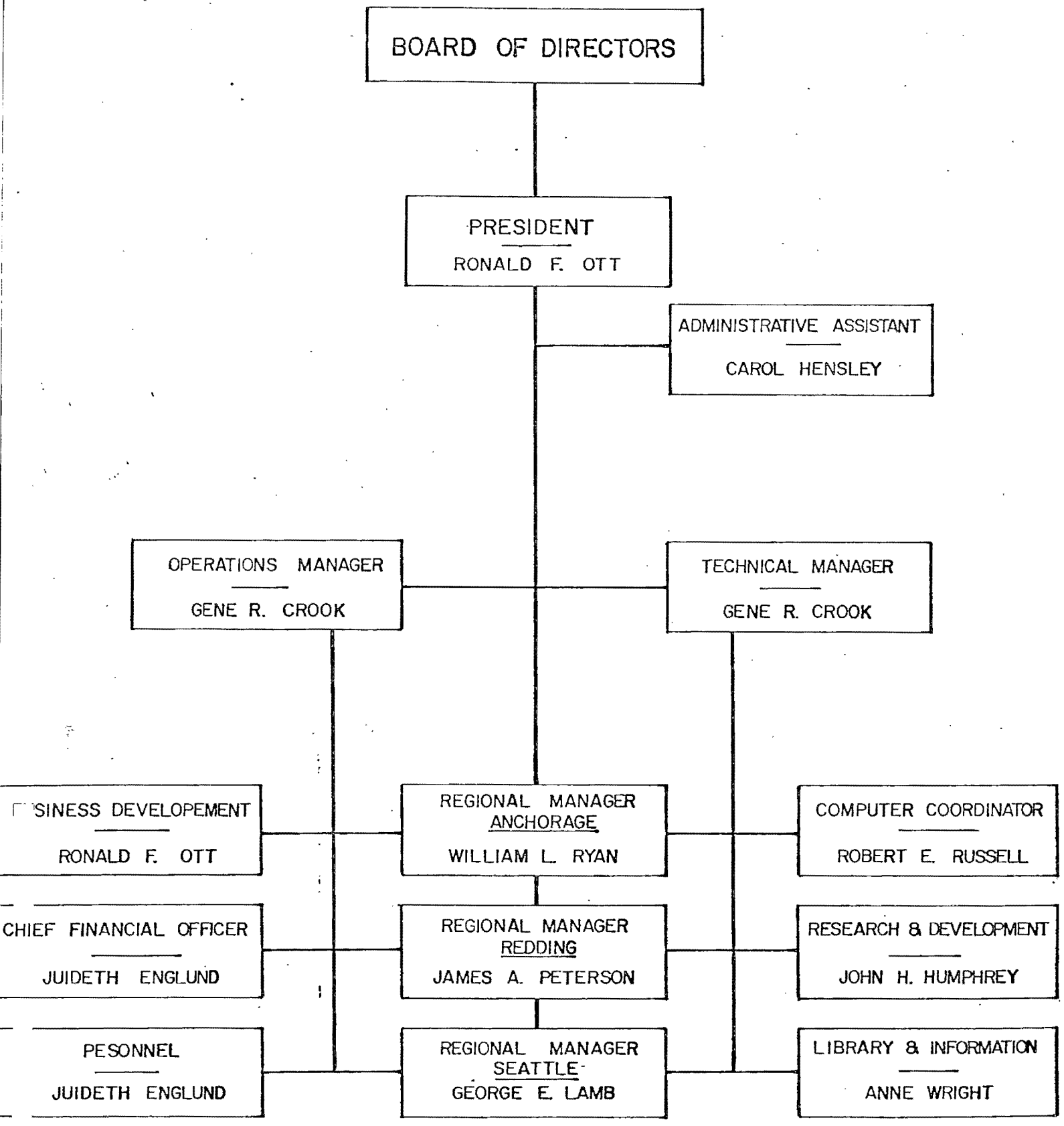
the combined sewer flows generated from this storm and the sanitary system from the city. Models were applied to determine pollutant loads caused by overflow into rivers. Expert witness services were provided for the city in a court case on combined sewer overflows.

FLOOD STUDY
REDDING, CALIFORNIA

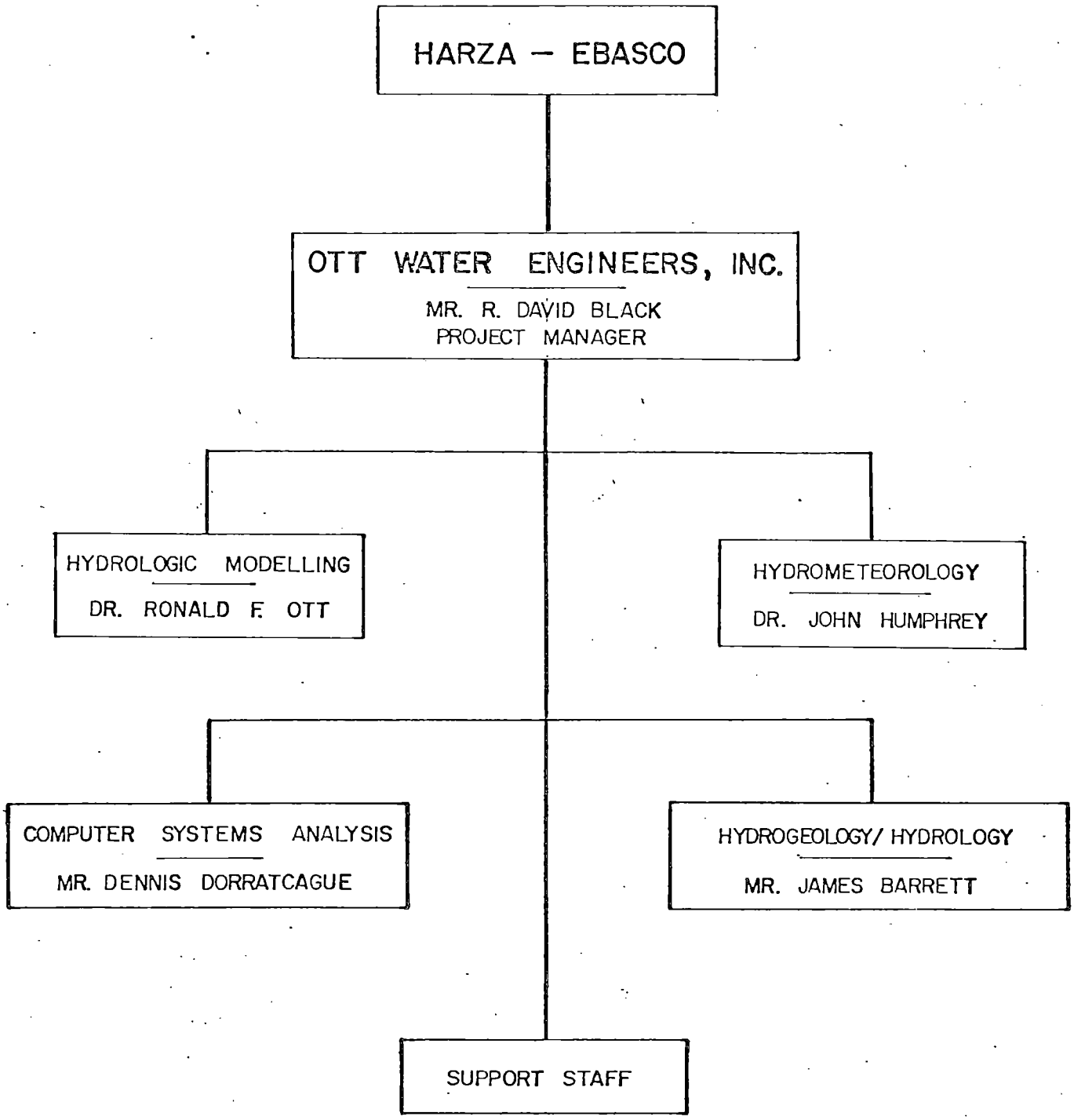
For the City of Redding, OTT determined the flood limits of Olney Creek for present and future urbanization conditions. The Shasta County Hydrology Manual was used to determine the 25- and 100-year flood hydrographs. The HEC-2 computer program was used to determine channel capacities. Stormwater management alternative combinations of channel improvements and upstream storage were tested. An inventory of potential dam and reservoir sites was conducted.

SECTION 4

4A CORPORATE ORGANIZATION



4B PROJECT ORGANIZATION



SECTION 5

5. PROJECT TEAM

OTT specializes in all aspects of water related engineering design and studies including hydrologic modeling and forecasting. Members of the proposed project team form a highly experienced and technically qualified group for streamflow forecasting analyses. Experience of individual team members is described below.

R. DAVID BLACK — PROJECT MANAGER

Mr. Black is a principal of OTT and has been selected as Project Manager because of his experience and water resources technical expertise. Over the past 11 years, he has gained experience in the planning and operation of numerous stream basin models throughout the United States.

He has been Project Manager for the development, application, and documentation of a computer model of the entire upper Wisconsin River system. Attributes of this model include snowmelt and runoff, streamflow routing, and reservoir operations for the 2,000-square-mile watershed. Mr. Black also was Project Manager for the Municipality of Anchorage Section 208 Area-Wide Waste Management Plan. Computer simulation of snowmelt and rainfall runoff in Campbell Creek was accomplished and a user's manual was prepared for application to similar studies.

As Project Manager, Mr. Black will be responsible for the overall direction of this feasibility study. He will organize the study efforts, schedule and assign tasks, and coordinate team efforts. He will be the primary liaison with the Harza-Ebasco Susitna Project Team and will be responsible for the successful completion of this study. His experience and successes in similar modeling assignments make him highly qualified for managing this project.

DR. RONALD F. OTT HYDROLOGIC MODELING

Dr. Ott is the President and senior engineer of the firm. He has managed numerous hydrologic and water quality modeling investigations since 1966 and has provided expert testimony for hydrology-related litigations. Dr. Ott's expertise in hydrodynamics and hydrologic modeling is represented in his expertise in water resource investigations throughout the United States. Specifically, he has developed models to predict: water quality and quantity of runoff from rural and urban watersheds; sizing of sewer overflow systems; water quality modeling for pulp paper industries; and numerous bridge backwater and floodplain evaluations. He is also a noted expert in the development and assessment of hydrologic resources for power generation including impacts to fisheries. Since forming OTT he has been involved with modeling efforts for over 200 hydroelectric projects.

Dr. Ott's experience and expertise in hydrologic modeling will provide the project team with a firm foundation for this project. He will advise team members in the model evaluation and selection process described in the technical scope of services.

DENNIS E. DORRATCAGUE COMPUTER SYSTEMS ANALYST

Mr. Dorratcague is a principal of OTT and since 1972 has specialized in the field of computer modeling and hydrodynamics. His recent experience includes cold regions modeling of storm surges along the Arctic Ocean coastline. His cold regions modeling experience and knowledge of computer system capabilities will be an asset to this feasibility study. As described in the technical scope of services, he will compare available methods and select the most suitable means of simulating streamflows. He will also provide cost estimates for the computer operation (hardware and software), investigate the availability of the selected program, identify necessary system modifications, and estimate costs to set up and run the program.

DR. JOHN H. HUMPHREY — HYDROMETEOROLOGIC ANALYSIS

Dr. Humphrey, a principal of OTT, brings 20 years of hydrologic and meteorologic expertise to the team. He has modeled over 150 watersheds throughout the western United States to predict the feasibility of hydroelectric projects. Using a program developed by OTT (FLODUR), annual hydrographs and flow exceedence values are simulated for specific site conditions. The program has the capability to assimilate gaged hourly flow records modified for local site conditions. Dr. Humphrey's cold regions experience includes the preparation of a hydrologic atlas for the Chugach and Tongass National Forests in Southcentral and Southeastern Alaska. This atlas presents predictive formulas derived by OTT for determination of mean monthly flows, flow duration statistics, and peak and low flow rates. Additionally, Dr. Humphrey conducted hydrologic analyses of 50 potential hydroelectric sites throughout Northwest Alaska for the U.S. Army Corps of Engineers. For the Susitna study he will review the suitability of available weather and streamflow data to provide model requirements for precipitation, snowmelt, glacier storage, and runoff data.

JAMES K. BARRETT — GEOHYDROLOGIC ANALYSIS

Mr. Barrett is an experienced hydrologist with 11 years of experience in the analysis of surface and groundwater interrelationships. His knowledge of cold regions data collection networks, field programs, and hydrologic experience is exemplified by numerous baseflow and flood investigations, major water supply projects, and bridge and port design efforts. As senior hydrologist for OTT's Alaska region he has been responsible for the design, installation, operation, maintenance, and data analysis of gaging and recording systems for major industrial development projects throughout the state. These projects include basic data collection and monitoring programs for 3 of the 4 world class mining projects in Alaska (Diamond-Alaska Beluga Coal Mine, Cominco-Alaska Red Dog Mine, and Noranda Mining's Greens Creek Project); the Eklutna Water Project (the biggest municipal water project in state history); and Alaska Department of Fish and Game's Elmendorf and Ship Creek Hatcheries' water supply development (15-million-gallon-per-day well field). Moreover, Mr.

Barrett has developed and supervised operation of the largest electronic recording stream gaging and water quality monitoring network in the state. This network, established for the Diamond-Alaska Coal Mine project, encompassed over 24 electronic digital stream gaging stations, rain gages, and water quality monitoring installations. Data collected from these sites is stored on solid state microchips, electronically transmitted to computer storage and processed through known stage discharge relationships to prepare hydrographs, flow duration curves, and other hydrological and statistical analyses. For the Susitna study he will determine the data requirements, and cost and magnitude of monitoring networks and measurement programs to provide necessary model input.

SECTION 6

6. SCOPE OF WORK

Task 1: Evaluation of modeling requirements for streamflow forecasting in the Susitna Hydroelectric Project area

Essentially, APA requires a predictive methodology that offers cost effective analyses of various reservoir operational scenarios. Moreover, the model effort must be coupled to a reliable, short-term and long-term streamflow forecasting methodology to achieve significant conclusions. Model requirements include its applicability to a large, multiple tributary stream basin, reservoir and river routing capability, long-term forecasting from snow pack and seasonal or monthly climatological data, short-term forecasting from daily or six-hourly time step weather forecasts, and the ability to incorporate glacier mass changes. These requirements will be identified in greater detail and form part of the initial selection criteria matrix. In fact this task can be considered as a primary filter that will identify and reject those models that cannot fulfill the project goals. In this manner, the criteria matrix will be applied in detail to the remaining models that have a documented history and demonstrated performance capability.

Task 2: Capabilities of existing streamflow forecasting models

Our modeling and field instrumentation experience will be combined with comprehensive literature research to define the application, capability, and costs of the complete field instrumentation and modeling system. Existing technical reports from private consultants, the National Weather Service Forecasting Center, Alaska state agencies, U.S. Geological Survey, U.S. Army Corps of Engineers, and other municipal agencies and organizations throughout the western United States and Alaska will be evaluated to determine data acquisition costs, modeling costs, and output accuracy. To be significant to this project, the cost of the monitoring network used in each report evaluated will be determined based on the installation and operational expense of a similar sized network within the Susitna River basin. Model output accuracy will be addressed by comparing the future predictions within each evaluated

report to actual conditions that occurred after the report was published. In this manner, we will be able to provide APA with comparisons between differing methodologies based on actual operational histories. Additionally, each individual methodology will be evaluated for its output accuracy versus monitoring network density and duration so that an optimal system may be selected.

Our experience has shown that the most cost effective and useful model information is available from the USCOE/NWS Columbia River forecasting center, the California DWR/DNR Sacramento forecast center, and the upper Mississippi NWS forecast center in Minneapolis. Existing models with the most potential to meet this project's requirements are the U.S. Army Corps of Engineers SSARR model, the SAC-SMA model as modified by Burnash and Ferral, the NWS River forecast system, and the Stanford watershed model (in various versions) with routing and Eric Anderson's snowmelt modifications.

Task 4: Selection criteria for modeling system

A selection criteria matrix will be established for detailed evaluation of the models that were identified for further analysis in Task 1. In general, criteria to be evaluated include software availability, memory and storage requirements, ease of operation, documentation (complete and usable), operational experience, set-up cost, calibration and forecasting cost, data input cost, and output format options. These criteria should be met if there is potential for use of this model as an operational model for reservoir releases, etc. An operational model should be easy to operate (user friendly), have a documented history of use, and be well known in case future modifications or adjustments are required. More detailed evaluation would be made of model routing procedures (availability of options such as kinematic wave, muskingum, lag attenuation, glacier routing); time steps (hourly, daily, monthly); length of simulation; snowmelt routines (availability of options such as degree-day index, energy balance, snowpack accumulation, frozen ground, distributed model for elevation zones); snowpack variables (depth, water content, albedo, cover, etc.); meteorological data requirements (temperature, dew point, wind speed, precipitation rate, etc.); and

infiltration routines (availability of options such as Hortons, constant rate, SCS curve methods, etc.). Additionally, simulation accuracy versus expense (evaluated in Task 2) will be used to select the most optimal modeling system to meet APA's needs.

Task 5: Data requirements for the selected modeling system

Suitability, modification, and application of existing data to the modeling system will be described. Data requirements for a range of forecasting accuracy and cost for both short term and long term forecasts will be described. For a range of these alternatives, requirements for stream gages, meteorological stations, and telemetry will be determined.

Task 6. Recommended set-up of modeling system

Set-up and operation of the selected modeling system will be described for at least five alternatives covering a range of accuracy and cost. Sensitivity testing derived from previous use of the modeling system and examination of its internal program will be provided in terms of data input requirements, costs, and accuracy.

Task 7. Report

A comprehensive report will be provided describing the methodology and results of the tasks in this work plan. An annotated bibliography will be provided of all appropriate modeling techniques identified in this study.

SECTION 7

7. COST ESTIMATE

I. SERVICES

A. Salaries

Title	Man Hours	Salary Rate	Cost
Dr. R.F. Ott, Hydrologist (project review)	10	31.67	316.70
R. David Black, Project Manager	30	31.84	955.20
Dr. John Humphrey, Hydrometeorologist	120	31.84	3,820.80
James Barrett, Hydrologist	120	22.51	2,701.20
Dennis Dorratcague, Hydraulics Engineer	10	21.56	215.60
Joanne Richter, Report Coordinator	60	20.20	1,212.00
Anne Wright, Librarian	40	7.77	310.80

TOTAL A SALARIES = $ 9,532.30

B. Salary Related Costs (22.38%A)

Subtotal = $ 2,133.33

C. Overhead (152.66% A&B)

Subtotal = $17,808.75

D. Fee on Services (12% (A&B&C))

Subtotal = $ 3,536.93

TOTAL I-A through 1-D = $33,011.31

II. DIRECT EXPENSES

A.	Travel & Living Expenses	None
B.	Telephone	200
C.	Reproduction	100
D.	Computer Charges (literature search)	300
E.	Other (typing services)	1500

TOTAL II-A through II-E = $ 2,100.00

III. SUBCONTRACTS — TOTAL III — None

(Provide detail as above in I and II)

TOTAL PROJECT COST = $35,111.31

PERSONNEL WORK LOAD BY MONTH

Month	Ron Ott	Dave Black	John Humphrey	Dennis Dorratcague	Jim Barrett
November	52	70	52	67	56
December	63	67	45	58	48
January	54	65	27	62	52
February	25	55	35	54	46
March	30	60	20	31	35
April	25	45	15	35	22
May	20	42	15	40	15
June	20	35	15	43	10

SECTION 8

R. DAVID BLACK
Water Resources Engineer

EDUCATION

B.S., Civil Engineering, Water Resources Specialty, University of California, Davis
Graduate Degree Program, Civil Engineering, Cold Regions Water Resources, University of Alaska, Anchorage

EXPERIENCE

Mr. Black is a principal associate of Ott Water Engineers, Inc. (OTT). Since 1973, Mr. Black has gained water resources engineering experience throughout the United States. He has specific experience in water quality, surface and groundwater hydrology, coastal flooding, hydraulics, computer simulation, water rights, and reservoir operation.

In 1978, Mr. Black helped form OTT. Since that time, his major project experience in Alaska has been:

- Project Director of wastewater facilities plan for the Municipality of Anchorage. Developed 40-year construction program for wastewater collection, treatment, and disposal alternatives.

- Project Manager of hydrologic and hydraulic analyses for dam safety inspections at Squaw Valley and Slate Creek Dams, Alaska. Computed PMF and routed floods through reservoir and over spillway.

- Project Manager for three drainage plans for the Municipality of Anchorage: South Glenn Highway storm drain, Little Campbell Creek drainage basin, and Little River Creek drainage basin. Projected future saturation development conditions; developed design storm events; simulated rainfall and snowmelt runoff, and pollutant washoff with the system analysis model (SAM); developed pipe and ditch networks; computed capacity requirements; and developed water quality control plans.

- Project Manager for test well program and aquifer analysis in Eagle River, Alaska. Determined water supply potential based on pump test information.

- Project Manager for the regional inventory and reconnaissance level study of potential feasibility of hydroelectric power development in fifty northwest Alaska communities. Performed hydrologic and environmental baseline studies for environmental impact assessment.

- Participated in hydrologic and environmental baseline studies for assessment of potential impact of developing a marine industrial park at Seward, Alaska. Assisted in preparation of environmental assessment document and permit coordination with federal and state resource agencies.

- Project Manager of the Municipality of Anchorage Comprehensive 208 Wastewater Management Plan for Campbell Creek. Plan involved assessment of pollution impact using runoff and water quality computer modeling.

- Responsible for preliminary design, economic analysis, coordination with agencies, and securing of all permits required for development of a small hydroelectric facility in Akutan, Alaska.

- Project Manager for preliminary designs, cost estimates, and report relating to U.S. Army Corps of Engineers (USCOE) Chena River Lakes Flood Control Project, Fairbanks, Alaska. Entailed relocation and modification of levee, pumping plant, power supply, and major gravity drainage channels.

- Chief investigator of the effect of snow disposal operations on the quality of groundwater in the Municipality of Anchorage.

- Assessed hydrologic impacts of extracting gravel materials at potential sites on the North Slope of Alaska. Assisted in environmental evaluation and project description for submission to permitting and commenting resource agencies.

- Project Manager of HEC-2 backwater profile, levee completion plans, and levee seepage analysis, Tanana, Alaska.

Other major project experience with OTT includes:

- Project Manager for development, application, and documentation of snowmelt and rainfall runoff, stream routing, and reservoir operation computer models for over 2,000 square miles of the upper Wisconsin River watershed. Performed extensive computerized data management.

- Determined the effect of a light commercial/industrial development on the quality of water discharging from Big Springs near Mount Shasta, California.

- Project Manager of hydrologic and hydraulic analyses for Phase I dam safety inspections for six dams in southwestern Utah. Computed the PMF for cloudburst and general winter storms using the SCS curve technique and a unit hydrograph approach. Determined outlet, spillway, and dam overflow rating curves.

- Project Manager for a stormwater drainage design in Palo Cedro, California. Determined 25-, 50-, and 100-year flood flows; computed hydraulic capacity of various channel and culvert designs.

- Analyzed performance of, and recommended improvements to, existing water systems on eight Indian rancherias in northern California for the U.S. Bureau of Indian Affairs, and identified potential reservoir sites.

- Performed water quality, benthic invertebrate, and sediment sampling on Manzanita Creek, a tributary to the Trinity River in California. Determined population estimates of fingerling steelhead trout using electroshocking equipment. Prepared a water quality baseline to analyze the effect of future controlled burns on the anadromous fishery.

Between 1974 and 1978, Mr. Black was a staff engineer in the Hydrologic and Environmental Sciences discipline of a large engineering consulting firm. His project experience during that time includes:

- Project Manager for Section 208 areawide waste management plan for the Municipality of Anchorage, Alaska. Emphasized computer simulation of the effects of snowmelt and rainfall runoff on the quality of water in Campbell Creek and developed a manual of methods to accomplish similar studies by the municipality staff.

- Modified and applied the QUAL III water quality computer model to the Wisconsin and Fox Rivers in Wisconsin to assess the impact of industrial wasteload allocations. Simulated the growth and decay of eleven water quality constituents using a state-of-the-art investigation of sediment oxygen demand.

- Developed a conjunctive use reservoir operations model of Clear Lake and Indian Valley Reservoir, California. Model was used extensively by Yolo and Lake Counties to maximize benefits to both counties from conjunctive operation of the reservoirs.

- Project Engineer for U.S. HUD Flood Insurance Studies along the Pacific Northwest coast. Developed methods for analysis of coastal flooding, and determined magnitude and frequency of storm surge, sea swell, and astronomical tide. Used storm surge, ocean wave track, and hydrodynamic estuarine computer models.

- Reported on California groundwater rights for Redding Regional Water Study. Investigated declining water well yields, designed and determined costs of water well construction, and developed a water well simulation program.

- Investigated effect of land application of potato process wastewater on groundwater quality in Maine.

- Determined the availability of groundwater as a source of water for offshore oil drilling in Cook Inlet, Alaska. Analyzed existing information from the U.S. Geological Survey and the Alaska Department of Natural Resources and compared it to projected water requirements of offshore drilling platforms.

- Performed field location and construction inspection of over twenty groundwater quality monitoring wells at a pulp and paper effluent land disposal site adjacent to the Sacramento River, California.

PROFESSIONAL REGISTRATIONS

Professional Engineer, Alaska and California

MEMBERSHIP IN ORGANIZATIONS

American Society of Civil Engineers
American Water Works Association

PUBLICATIONS AND PRESENTATIONS

"Influence of Temperate Glaciers on Flood Events in Maritime Alaska" (co-authors John H. Humphrey, Carole J. Newton), Proceedings, Alaska Section of American Water Resources Association, 1984.

"Determination of Flood Levels on the Pacific Northwest Coast for Insurance Studies" (co-authors D. Dorratcague and J. Humphrey), Proceedings, Hydraulics Specialty Conference, College Station, Texas, American Society of Civil Engineers, 1977.

RONALD F. OTT
Civil Engineer

EDUCATION

Ph.D., Civil Engineering, Stanford University
Engineer, Civil Engineering, Stanford University
M.S., Civil Engineering, Stanford University
B.S., Civil Engineering, California State University, Chico

EXPERIENCE

Since 1966, Dr. Ott has been a private consultant to government agencies, municipalities, and industries. During this time, he has completed projects in the fields of hydropower, hydrology, hydraulics, water quality, water resources, water rights, and groundwater. Dr. Ott has worked directly with the Federal Energy Regulatory Commission (FERC), Department of Energy, U.S. Army Corps of Engineers, U.S. Forest Service, U.S. Fish and Wildlife, State Fish and Game, water quality control boards, and local agencies to obtain permits for hydropower and complicated environmental projects. He has served as expert witness involving hydrologic and water quality impacts and has taught courses on how to build and maintain small hydroelectric projects.

Dr. Ott formed Ott Water Engineers, Inc., in January 1978. Samples of the types of projects on which he has been a senior consultant or manager are listed below:

- Hydropower site selection and feasibility studies for the Tuolumne Regional Water District. Seven sites were studied for hydropower potential in the Tuolumne and Stanislaus river systems, totaling over 20 megawatts (mW). Detailed work plans were developed to prepare FERC licenses and construct the projects at the two largest sites.

- FERC licensing for four power projects and two dams for the Oroville/Wyandotte Irrigation Districts. Projects totaled over 60 mW and are located on the Feather River system.

- Hydropower site selection and feasibility studies on streams in Alaska, California, Oregon, and Nevada for energy development companies.

- FERC licensing State and regulatory permits for a 1.4 mW hydroelectric project on Winchester Dam on the North Umpqua River in Roseburg, Oregon. Design, construction, and management being conducted for the Winchester Water Control District and Elektra Power Corporation.

- Preliminary design, FERC licensing, and State and local permitting for a 1.2 mW project on Hat Creek, California.

- Pre-design, FERC licensing, and power purchase contracts for a 3.6 mW hydroelectric project on Battle and Digger Creeks in Northern California.

- Short-form license for a 5 mW project on Hatchet Creek, California. This work also included IFG-4 type work for the license.

- FERC short-form licenses and exemptions for private energy companies on streams and dams throughout Northern California.

- Filed and had granted over 200 preliminary FERC permits to generate hydropower on streams, lakes, and dams in California for municipalities, private energy companies and individuals.

- Project manager on the Bailey Creek Hydroelectric Project in Northern California. This was the first project in the Western United States to receive a FERC exemption under the 5 mW status of the 1980 FERC ruling for a run-of-river project. The project is now generating power to PG&E.

- Hydropower feasibility study for tailings dam for Noranda Mining, Inc., in the Klamath River Basin in Northern California.

- Hydropower site selection, feasibility studies, and FERC licensing for projects on streams in Alaska, California, Oregon, and Nevada for energy development companies.

- Feasibility studies, FERC licenses and design, and construction management for private hydro developers on projects under 5 mW in California and Alaska.

- Hydropower feasibility studies including hydrological, environmental, and economic investigations on 50 sites in Northwest Alaska for the U.S. Army Corps of Engineers.

- Hydropower feasibility and permitting for sites on Spring and Boulder Creeks, California, for Iron Mountain Mines.

- Open-ended contractor providing assistance to Department of Energy to provide technical assistance on small hydroelectric projects in Oregon, California, and Nevada.

- Dam safety inspections and hydraulic analysis for six dams in Utah for Utah Division of Water Rights.

- Water quality modeling of the Wisconsin and Fox Rivers, Wisconsin, for pulp paper industries, Wisconsin Department of Natural Resources, and power industries to determine the effects of and to establish NPDES permits.

- Water resources study for M&I water supplies and needs in the Truckee River Basin, California and Nevada, for the U.S. Bureau of Reclamation.

- Hydrological and environmental studies on the Sacramento River and tributaries for hydropower, litigation, and planning purposes.

Prior to creating Ott Water Engineers, Inc., Dr. Ott consulted for ten years for a major consulting firm of which the last six years were as Director of the Environmental and Hydrologic Sciences Discipline. Representative projects in which he was involved were:

- Performed hydraulic studies for a hydropower plant on the Sacramento River for the City of Redding, California.

- Developed comprehensive quality and quantity models for streams, rivers, lakes, and estuaries for Lake Washington and Green River drainage basins in the Seattle, Washington, area. Models include firm yield operation models for hydropower and water supply reservoirs.

- Represented the California Attorney General's Office in an interagency task force to develop hydrologic models for the Sacramento River to be used in flood damage litigation.

- Developed models to predict runoff and runoff quality from forest, agricultural, and urban lands and their effects on the San Joaquin River, Sacramento River, and the Delta for the California Water Resources Control Board. Models included water releases from hydroelectric and other dams around the rim of the Sacramento and San Joaquin Valleys.

- Water resource and water quality management studies for Anchorage, Denver, St. Louis, Charleston, and other major cities and geographical areas in the U.S.

PROFESSIONAL REGISTRATIONS

Engineer: California, Montana, Nevada, Washington, and Wisconsin
Water Rights Surveyor: Nevada

MEMBERSHIP IN ORGANIZATIONS

American Society of Civil Engineers
International Water Resources Association
Sigma XI

COMMUNITY AND PROFESSIONAL SERVICES

Sacramento Valley Water Task Force, 1983
Vice President, Redding Chamber of Commerce, 1981
Board of Directors, Redding Chamber of Commerce, 1979-1981
Chairman, Redding Chamber of Commerce, Natural Resources Committee
Technical Paper Reviewer, Environmental Journal, ASCE, 1976-Present
Member, Rotary International, Redding-East

PUBLICATIONS

A Steady State Simulation of Small Amplitude Wind-Generated Waves, (with E. Y. Hsu and Robert L. Street), Technical Report No. 39, Department of Civil Engineering, Stanford University, August 1968.

Streamflow Frequency Using Stochastically Generated Hourly Rainfall, Technical Report No. 151, Department of Civil Engineering, Stanford University, December 1971.

"Streamflow Frequency Using Stochastically Generated Rainfall," (with Ray K. Linsley), Proceedings of the International Symposium on Uncertainties in Hydrologic and Water Resource Systems, Tucson, Arizona, December 11-14, 1972.

Water Quality Simulation and Application, (with Pio S. Lombardo), paper presented at the Eighth American Water Resources Conference, St. Louis, Missouri, October 30, 1972.

Modeling Water Temperature in Lake Washington and Green River Drainage, (with T. W. Holz and G. D. Farris), paper presented at the Ninth American Water Resource Association Conference, Seattle, Washington, October 14, 1973.

A Simulation Model for Water Quality Management in the Upper Duwamish River Estuary, (with J. A. Layton, T. J. Bechtel, and J. M. Buffo), paper presented at the Symposium on Modeling Techniques for Waterways, Harbor and Coastal Engineering, San Francisco, California, September 3, 1975.

Storm Analysis and Combined Sewer Overflow Storage, paper presented at Pipeline '78' Conference, sponsored by SEWCPA, Milwaukee, Wisconsin, February 16, 1978.

Instructed Course on Building and Operating a Small-Scale Hydroelectric Power Plant at the University of California, Berkeley, January 27-28, 1982, and January 26-27, 1983.

Environmental Barriers to Hydro Development - The Instream Flow Problem, paper presented at the National Alliance for Hydroelectric Energy, San Francisco, California, May 4, 1982.

Small-Scale Hydropower Development on the Flathead Reservation, paper presented at "Energy Independence: A Challenge for Native American Communities", American Indian Studies, University of California, Los Angeles Center, April 15-16, 1983.

DENNIS E. DORRATCAGUE
Civil Engineer

EDUCATION

M.S., Civil Engineering, Colorado State University, 1974
B.S., Aerospace Engineering, University of Notre Dame, 1968

EXPERIENCE

Mr. Dorratcague is a principal of Ott Water Engineers. He has been working in the field of hydrology and hydraulics since 1972. His main area of concentration has been computer modeling of hydrodynamics and water quality. His experience on projects includes the following:

- Developed cost and hydrologic computer algorithm models for the Northwest Power Planning Council's Hydropower Data Base. This included calculation of energy costs and development of a standard procedure for hydrologic analysis for the Northwest states.

- California coastal storm surge analysis. Used the CAFE1 storm surge model (developed by MIT) to model storm surge at several sites along the California coast for the Federal Emergency Management Agency.

- Performed the two-dimensional hydrodynamic and water quality modeling of Lake Wisconsin. Currents due to reservoir operation and winds were modeled. Nine water quality constituents were also simulated and the resulting model was employed to evaluate waste discharges from a proposed industrial plant.

- Managed and performed the numerical modeling of storm surges on the coast of the Arctic Ocean. One model was a finite difference model covering a large area. The other was a finite element model applied in greater detail to simulate surges in Prudhoe Bay.

- For Intersea Research Corp., used finite difference computer simulation models to analyze coastal storm surges at Hoonah, on the coast between Valdez and Cordova, and four sites off Prudhoe Bay including Dinkim Sands.

- For the City of Nome, Alaska, determined the wave and storm surge levels and predicted impact upon a proposed wastewater treatment plant upgrading.

DENNIS E. DORRATCAGUE

- Responsible for flood insurance studies on the Washington and Oregon coasts. Work included analysis of storm wave runup on beaches and storm surges on the coast and in bays and estuaries with river flow inter-relations. Mr. Dorratcague developed two-dimensional coastal surge and wave tracking models which have been adopted by the Flood Insurance Administration for use on the Pacific Northwest Coast.

- Performed a water quality modeling study on the Humboldt River in Nevada. Loaded the QUAL3 water quality model on the State of Nevada's IBM computer system. This model was run to simulate 12 water quality constituents along 340 miles of the Humboldt River, and nonpoint source salinity contributions were analyzed.

- Performed a water quality modeling study for two non stratified reservoirs and a 20-mile reach of the Wisconsin River in Wisconsin. Eleven water quality constituents were modeled with emphasis on dissolved oxygen levels during critical low flow periods.

- Employed hydraulic and hydrologic computer analyses for a flood control feasibility study of the Humboldt River and its tributaries in Nevada utilizing HEC-1 and HEC-2.

- Developed and applied hydraulic models for unsteady flow simulation on the Fox River, Wisconsin and the ship canal in Stockton, California. Output from these models was used for input to the water quality models. Mr. Dorratcague applied a similar model to determine tidal flood levels on Hood Canal, Washington.

- Applied a two-dimensional groundwater model to determine the effect on the water table at an effluent disposal site. He also developed a computer model to investigate the mutual drawdown effects of a well field for an irrigation project.

- Acted as technical manager on the Green River-Flaming Gorge water quality study. Added a sulfate routing routine to the Corps of Engineers' water quality program, WQRRS. This program was then applied to model 21 water quality constituents on 90 miles of the Green River and stratified Flaming Gorge Reservoir.

DENNIS E. DORRATCAGUE

PROFESSIONAL ENGINEER REGISTRATION

Washington, Oregon, Alaska, California

MEMBERSHIP IN ORGANIZATIONS

American Society of Civil Engineers
Tau Beta Pi--Honorary Engineering Society

PUBLICATIONS

"Determination of Flood Levels on the Pacific Northwest Coast for Federal Insurance Studies," (Co-authors R. Black and J. Humphrey). Proceedings, Hydraulics Specialty Conference, College Station, Texas, American Society of Civil Engineers, 1977.

"Numerical Simulation of Storm Surges on the Pacific Northwest Coast," (Co-author J. Humphrey). Proceedings, Conference on Coastal Meteorology, Virginia Beach, Virginia, American Meterological Society, Boston, Massachusetts, September 21-23, 1976.

Remote Sensing of Mississippi River Characteristics, (with J. F. Ruff, M. M. Skinner, D.B. Simmons, and B.R. Winkely), Journal of Waterways, Harbors, and Coastal Engineering Division, American Society of Civil Engineers, May 1976.

JOHN H. HUMPHREY
Hydrologist/Meteorologist/Civil Engineer

EDUCATION

Ph.D., Hydrology, University of Nevada at Reno, 1972
B.A., Meteorology, University of California at Los Angeles, 1963

EXPERIENCE

Since completing graduate studies, Dr. Humphrey has worked for engineering consulting firms providing hydrometeorological expertise, including:

- Determining flow duration statistics and synthesizing longterm daily flow records for hydropower facility design.
- Synthesizing design storms and depth-duration-areal frequencies of precipitation for stormwater runoff analysis.
- Determining flood peaks and volumes by computer simulation and by graphical, empirical, and regional methods.
- Analyzing surface and subsurface runoff, groundwater recharge, and evapotranspiration for different land uses.
- Setting up, calibrating, and verifying snowmelt runoff models for use in operational river system simulations.
- Providing meteorological data input to computer modeling of water quantity and quality in rivers and lakes.
- Estimating diffuse waste source contributions to water pollution, especially agricultural return flow and urban sediment washoff.
- Determining meteorological factors affecting coastal storm surges, ocean currents, wave forces, and other oceanographic studies.
- Selecting and installing hydrological and meteorological instruments, including telemetry equipment.
- Describing and analyzing meteorological factors affecting project siting, design, construction, operations, and air pollution.
- Performing climatological, hydrological, and water quality impact analyses in environmental assessment reports for the mining industry.

Dr. Humphrey spent 4 years as a graduate research fellow in hydrology at the University of Nevada where he developed a computer model for predicting snowmelt, water content, and temperatures in snow cover. His experience also includes 5 years as a meteorologist with the U.S. Air Force, where he is now a reserve Major.

JOHN H. HUMPHREY

PROFESSIONAL REGISTRATIONS

Civil Engineer - California
Certified Consulting Meteorologist

MEMBERSHIP IN ORGANIZATIONS

American Meteorological Society
American Water Resources Association
U.S. Air Force Reserve
International Glaciological Society

PUBLICATIONS

The Response of Sapflow Patterns in Forest Vegetation to Meteorological Parameters in the Eastside Sierra Nevada, University of Nevada Agricultural Experiment Station, 1972.

Numerical Prediction of Snowpack Temperatures in the Eastside Sierra Nevada Using a Surface Energy Balance Model, (Ph.D. dissertation) 1972, University of Nevada at Reno.

Allocation of Water Resources in the Lake Washington-Cedar River Basin, Washington, (Co-author W. Blood), presented at the Ninth American Water Resources Conference, Seattle, Washington, 1973.

Variation of Snowpack Density and Structure with Environmental Conditions, (Co-author C. Skau), Center for Water Resources Research, Desert Research Institute, University of Nevada System, Reno, Nevada, 1974.

"Numerical Simulation of Storm Surges on the Pacific Northwest Coast", (Co-author D. Dorratcague), Proceedings, Conference on Coastal Meteorology, Virginia Beach, Virginia, American Meteorological Society, Boston, Massachusetts, September 1976.

"Determination of Flood Levels on the Pacific Northwest Coast for Federal Insurance Studies", (Co-authors R. Black and D. Dorratcague), Proceedings, Hydraulics Specialty Conference, College Station, Texas, American Society for Civil Engineers, 1977.

"Estimating Flows in Unstable Channels Using Indirect Methods" (Co-author M. Randall), Rivers '83, Proceedings of a Hydraulics Specialty Conference in New Orleans, Louisiana, American Society of Civil Engineers, October 1983.

"Influence of Temperate Glaciers on Flood Events in Maritime Alaska" (Co-authors R. Black and C. Newton), Managing Water Resources for Alaska's Development, Proceedings of an American Water Resources Conference, Chena Hot Springs, Fairbanks, Alaska, November 1983.

Reservation Resource Development Plan (Co-authors M. Sunday and R. Black), presented to the Presidential Commission on Indian Reservation Economics, Reno, Nevada, March 5, 1984.

"Modeling Design Flood Hydrographs for Glaciated Basins in Alaska" (Co-authors R. Black and C. Newton), Proceedings Cold Regions Specialty Conference, April 4-6, 1984, Edmonton, Department of Civil Engineering, University of Alberta.

JAMES K. BARRETT
Hydrologist

EDUCATION

M.S., Hydrology, Colorado State University
B.S., Geology, University of California, Davis
B.S., Civil Engineering, University of California, Davis

EXPERIENCE

Mr. Barrett joined Ott Water Engineers, Inc. (OTT) in 1979 after successfully completing his graduate studies in Colorado. His studies emphasized the study of hydrology in relation to mining and industrial development, geothermal potential, and domestic utilization.

Over the past ten years, Mr. Barrett has participated in a variety of projects including the following:

- Currently performing hydrology and hydraulics investigations for both the Municipality of Anchorage's Eklutna Water Supply and West Interceptor Projects. These studies include stream cross section and thalweg profile surveys, statistical analyses of discharge data, and stream scour depth calculations for pipeline crossing designs at Ship Creek, Peters Creek, Fossil Creek, Campbell Creek, Eagle River, and Eklutna River near Anchorage. The crossing design hydrology/hydraulics inputs include 100-year flood flows, elevations, profiles, 100-year floodplain delineation, scour depth calculations, channel stability, and lateral migration rates as well as determination of flood risk and diversion requirements during construction.

- Evaluated flood risk, stream migration threat, and erosion and scour potential for 23 bridge crossings in Southeast Alaska. Studies included 50- and 100-year flood flows, water surface elevations, profiles, and scour depth recommendations for bridge design criteria.

- Conducted surface and groundwater hydrology and water quality studies in the vicinity of the Red Dog lead/zinc mine project in northwest Alaska. This study included the evaluation of groundwater base flow, water quality impacts of ore zone seepage into Red Dog Creek, and hydrometeorological relationships between storm events, streamflow, and water quality.

- Participated in design, installation, and operation of surface and groundwater monitoring networks and water quality sampling programs for Beluga coal mine and transportation corridor projects. Among other innovations, this project represents the first large scale use of electronic digital stream stage recorders and computerized data processing equipment for hydrology baseline studies in Alaska.

- Performed hydrology investigations for the port and transportation alternatives analysis for the Bering River coal development near Cordova, Alaska. This reconnaissance investigation provided bridge design criteria such as estimates of 100-year flood flows, floodplains, scour, channel stability, lateral migration rates, and glacier outburst flood potential of several major water courses in the region.

- Performed hydrologic studies for large, open-pit mine in northern California. Included geologic investigations for 420-foot-high dam, small hydropower plant, diversion structure, and spillway.

- Supervised and conducted aquifer analyses for surface mining activities in Colorado and Wyoming. These included determination of relationships between groundwater quantity/quality and aerial geology; groundwater chemistry and overburden mineralogy; establishment of surface and groundwater sampling networks and monitoring programs; and analysis of mining site geomorphology for erosion and sedimentation control.

- With the Colorado State Geological Survey, developed a statewide geothermal systems water quality monitoring program; prepared geologic maps of each thermal system; and assisted in subsurface exploration of thermal areas via deep drilling and geochemical techniques.

- For the California Department of Water Resources, participated in surface water hydrology and fluvial morphology investigations for large surface water diversion projects. These investigations included determination of 100-year flood magnitudes, sediment transport rates, localized scour conditions, channel stability, and channel bottom bed form analyses for design of large intake structures.

- For the U.S. Army Corps of Engineers, prepared field reports, geologic maps, and related materials; assisted in drill core logging, and cuttings analysis for deep foundation investigations; and conducted slope stability surveys.

MEMBERSHIP IN ORGANIZATIONS

Gamma Sigma Delta Honor Society, Colorado State University

PUBLICATIONS AND PRESENTATIONS

"Hydrology of the Red Dog Project Area, Western DeLong Mountains, Alaska," University of Alaska Seminar, Fairbanks, Alaska, 1983.

"Procedures Recommended for Overburden and Hydrologic Studies of Surface Mines," USDA Forest Service SEAM Program, General Technical Report INT-71, Intermountain Forest and Range Experiment Station, Ogden, Utah, 1980.

"An Appraisal of Colorado's Geothermal Resources," Colorado Geological Survey Bulletin 39, 1977.

"Geothermal Resources of the Upper San Luis and Arkansas Valleys, Colorado, Studies in Colorado Field Geology," Colorado School of Mines, Professional Contributions No. 8, 1976.

"Hydrogeological Data of Thermal Springs and Wells in Colorado," Colorado Geological Survey Information Series 6, 1976.

"Utilization of Geothermometer and Isotope Models in the Buena Vista Thermal Area, Colorado," Geological Society of America, National Convention, Denver, Colorado, 1976.