Department of
Hydrology and Water Resources

THE UNIVERSITY OF
ARIZONA®
TUCSON ARIZONA

College of Engineering and Mines
Building 11
Tucson, Arizona 85721
(602) 621-5082
FAX (602) 621-1422

July 16, 1997

Dr. Budhi Sagar
CNWRA
6220 Culebra Road
San Antonio, Texas 78228-0510

RE: Research Options for CNWRA at the Apache Leap Research Site, Superior, AZ in collaboration with the University of Arizona, Department of Hydrology and Water Resources.

Dear Budhi:

Thank you for your interest in exploring the potential benefit of completing ongoing work at the Apache Leap Research Site. As per the request by Neil Coleman (USNRC), please find identified below and on the attachment the key research components of our proposal for the work at the ALRS.

Most recently, the University of Arizona was awarded a 4 year contract (4/1/95-5/31/99) from the NRC for research to be conducted at all three facilities at the Apache Leap Research Site. After little more than a year into the contract, Congressional budget rescissions resulted in cancellation of all research funding from the NRC and our contract was terminated as of 3/31/97. We are currently covered by a no-cost extension until July 31, 1997. This proposal is to complete a portion of that work owing to the momentum established at the watershed site, and the availability of a doctoral student familiar with the existing data. A significant database now exists for the hydrologic and hydrochemical systems in the watershed and perched zone, and it is our belief that: 1.) completion of some small amount of field work, 2.) followed by construction of the database for future use and 3.) simulation of the transport through the fractured tuff section to the perched zone using the most reliable simulators, will be of benefit in evaluating DOE's license application.

It is our opinion that owing to the existing quantity of data at the Apache Leap Research Site, site and both student and faculty commitment, that we have a window in which several key technical issues of fundamental interest to NRC licensing can still be addressed in a timely manner.

Key issues can be rapidly investigated at this site relative to the protracted time frames and viability concerns faced at Yucca Mountain, because of the reduced field scale of this site, fewer restrictions to surface activity, and the significant body of antecedent research. Generic research in fractured unsaturated tuff can significantly expand the knowledge base regarding technical

questions facing the license application process for Yucca Mountain. Consequently, NRC's continued albeit minimal involvement makes sense at this site. Continued funding for the attached task would require approximately the $50,000. annual budget for the first year ($74,762 total including Indirect Costs) and only $47,000 total cost for the second and final year. This total including the 51% university indirect cost and is a budget slightly below 15% of the original annual spending level approved in the rescinded 4 year NRC contract.

The "two page" summary requested by Neil Coleman is attached for the project which is essentially only a slight modification of one of the original tasks. Our work has been discussed in numerous venues, most recently we have made presentations to the NRC staff in Rockville, Maryland, and twice to the ACNW. This is available as public record. In addition to the aforementioned published material, we will be pleased to make a presentation to CNWRA as the work progresses or as requested.

I must reiterate that our most serious current dilemma is the fact that our current NRC contract terminates on July 31, 1997, unless other funding is secured, or other arrangements are made.

Please notify me if you or your staff have any further questions or would like to discuss the material in more detail.

Sincerely,

R.L. Bassett, Professor
Principal Investigator
Email: bassett@hwr.arizona.edu

CC: Neil Coleman - USNRC ✓

**TASK 1. Chemical, Isotopic and Hydraulic Characterization of Focused Flow in Fractured Unsaturated Tuff on the Watershed Scale: Land Surface to Perched Water for Model Calibration and Intercomparison**

**Background:** The Apache Leap Watershed Site (51 ha) is a classical bare rock watershed type similar to that of Yucca Mountain (Bassett, 1997; Bassett et al., 1994) and contains a deep slant corehole and a vertical borehole, instrumentation for climate monitoring, and necessary flume and rain gaging instrumentation for a water balance determination. Core material has been characterized for moisture content ( Rhodes et al., 1996), hydraulic data using a newly designed large core pycnometer (Geddis et al., 1996), and other geologic properties (Davidson and Bassett, 1995; Woodhouse et al., 1995). Borehole geophysics and visual logging have identified fractures, zones of oxidation and perched zones (Hardin, 1996; Hardin and Bassett, 1995; Hardin et al., 1996; Bassett et al., 1997a,b; Davidson et al., 1997) and lab and field characterization of matrix and fracture saturated hydraulic conductivities have been completed (Woodhouse and Bassett, 1997). Chemical and isotopic compositions of gas and water from surface water, matrix water and perched water have also been determined. Rapid fracture flow of water though unsaturated tuff has been observed at the Apache Leap Site to depths in excess of 120 m. Confirmation of focused flow of "young water" has been obtained for water in matrix material adjacent to fractures, water emerging from fractures, and compositions of sampled perched zones. Pore water was obtained from core material by pressure extraction for water chemistry, and for both radiocarbon and tritium ages using a newly designed vacuum extraction device (Davidson et al., 1996). Uranium, sulfur, boron and carbon stable isotopes were measured in rapidly infiltrating fracture water and serve as natural tracers (Davidson et al., 1997; Hardin et al, 1997; Hardin, 1996).

**Objectives:**

1.) To provide a watershed scale fractured tuff data set that includes three dimensional geohydrology, geologic structure, and chemical data useful for calibration and intercomparison of modelling strategies for flow and transport in fractured unsaturated tuff.

2.) To conduct simulations of flow and transport using a coupled advection, dispersion, and reactive transport code which will result in predictions of flux through the tuff section. These simulations must incorporate the hydrologic data, including core hydraulic measurements, surface water balance data, and established boundary conditions, but also must be supported by the independently obtained chemical and isotopic data for both the unsaturated tuff section, the perched system, and fractures. Key related technical questions that are correlative to issues to be addressed at Yucca Mountain are:

i. Can the formation of the perched zone be predicted using bounding calculations constrained with measured hydraulic properties, existing boundary conditions, existing geologic and hydrologic data, and measured infiltration rates?

ii. Are simulated steady state conditions and travel times consistent with measured radioactive isotopes in this system?

iii. Do the isotopic and chemical data confirm predicted hydrologic fast pathways, and also support the existence of zones of slow infiltration?

iv. Are the various radioactive isotopes in agreement or is there a rational explanation for the inconsistencies in the indicated ages?

Field Experimental Approach: Requisite data yet to be obtained include fracture infiltration rates in the major fracture sets in the base of the watershed, preliminary geophysical survey to determine extent of perched water zones laterally and up gradient, regional chemical and isotopic data for the perched zone, regional scale monitoring of barometric and stressed responses of the perched zone, and multiyear watershed water balance for this fractured bare rock watershed. Completion of a 3D geocellular geologic model will be used to depict the modelling approaches used to simulate both matrix and focused fracture flow on the watershed scale. Independent verification will be provided by the chemical and isotopic data already available and the new values obtained for $^{36}Cl$, $^{14}C$, $^{11}B$, and $Cl/Br/SO_4$ ratios.

The recently discovered elevated $^{36}Cl$ values in the ESF at Yucca Mountain appear to be related to more permeable features and have been interpreted as bomb pulse in origin. The balance of the data set collected from the ESF to date suggests a range for the historical source term for $^{36}Cl$ and also constrains the travel time for matrix flow. The Apache Leap site has similar topographic, structural, and hydrologic components with know areas of rapid fracture transport to perched sections. The distribution of bomb pulse $^{36}Cl$ versus the natural background values will be investigated at this site to provide ancillary understanding of the background values of $^{36}Cl$ in tuff matrix known to be isolated from fractures, matrix adjacent to fractures and fracture influenced tuff sections, from land surface to depths of 200 m terminating in discrete perched water zones. Methods recently developed here at the University of Arizona using core material in flow-through cells are already in use for extracting $^{36}Cl$ to avoid interferences previously encountered by others from rock crushing of tuff samples prior to sampling. Other confirmatory isotopes and chemical compositional tracers will be examined ($^{14}C$, $^{3}H$, $^{85}Kr$).

Simulations will be conducted using either the coupled code HYDROFLOW and HYDROGEOCHEM and the recent modification LEHGC (Yeh, 1995) with which we have significant experience or the FEHM code currently used by USDOE for simulations at Yucca Mountain. Datasets will be compiled and made available for intermodel calibration by other laboratories as needed.

**Deliverables:**

Annual presentations will be made at the Center for Nuclear Waste Regulatory Analysis in San Antonio, Texas.

Final dissertation will be submitted for publication in peer reviewed journals and portions will be published as a NUREG.

**Schedule:**

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|---|---|
| Start Date: | August 1, 1997 |
| First Annual Presentation: | Summer 1998 |
| Final Presentation: | Summer 1999 |
| Document Submission: | Summer 1999 |
| Completion Date | July 31, 1999. |

## Budget:

| | Year 1<br>Aug. 1, 1997-Jul. 31, 1998 | Year 2<br>Aug. 1, 1998 - Jul. 31, 1999 |
|---|---|---|
| A. Personnel | | |
| 1 Doctoral Student (50% AY) | $17,100 | $17,647 |
| 312 Hours Summer@$21.06 | $6,570 | $6,570 |
| ERE (Students @ 0.014) | $331 | $339 |
| **Subtotal** | **$24,001** | **$24,556** |
| B. Travel | | |
| Annual Trip to CNWRA (2 persons/2 days @ air fare $450; lodging $67/night; per diem $38; taxi $30/day) | $1380 | $1380 |
| Trips to ALRS Field Site | | |
| 20 trips: @truck rental $7/day plus 200 miles at $.33/mile; per diem $26/day | $1980 | $1980 |
| **Subtotal** | **$3360** | **$3360** |
| C. Operations | | |
| Telephone/FAX( $60/mo.) | $600 | $600 |
| Copying ($25/mo) | $300 | $300 |
| Publication Charges | $750 | $750 |
| Office Supplies($30/mo) | $360 | $360 |
| Infiltrometer materials | $800 | |
| Software Upgrades | $1200 | $600 |
| Software Licenses(unix/plot/GIS) | $800 | $800 |
| Tape Backup/5gb external HD | $1250 | |
| Analyses | | |
| $^{36}Cl$ (10 @ $500/sample) | $5,000 | |
| $^{14}C$ (15 @ $400/sample) | $6,000 | |
| $^{11}B$ (20 @$150/sample) | $3,000 | |
| Inorganic Chemistry (22 @$50/sample) | $1,100 | |
| Laboratory Supplies | $925 | |
| **Subtotal** | **$22,085** | **$3410** |
| D. Total Direct Cost | **$49,446** | **$31,326** |
| E. Total Indirect Cost (51.2%) | **$25,316** | **$16,039** |
| **Annual budget** | **$74,762** | **$47,365** |

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