U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: CHARACTERIZATION OF INFILTRATION

PRESENTER: DR. ALAN FLINT
PRESENTER'S TITLE AND ORGANIZATION: HYDROLOGIST
U.S. GEOLOGICAL SURVEY
MERCURY, NEVADA
PRESENTER'S TELEPHONE NUMBER: (702) 295-5805

REGISTRY HOTEL, DENVER, COLORADO
JUNE 25-27, 1991
PURPOSE

- TO COLLECT NECESSARY INFORMATION TO DETERMINE THE CHARACTER OF THE UPPER BOUNDARY CONDITIONS FOR WATER FLUX AT YUCCA MOUNTAIN, BOTH PHYSICAL AND STATE HYDROLOGIC VARIABLES, WITH ENOUGH RESOLUTION FOR ADEQUATE USE OF HYDROLOGIC MODELS
OBJECTIVES

0 TO CHARACTERIZE INFILTRATION RELATED HYDROLOGIC PROPERTIES AND CONDITIONS OF THE SURFICIAL SOILS AND ROCKS COVERING YUCCA MOUNTAIN

0 TO CHARACTERIZE THE PRESENT DAY INFILTRATION PROCESSES AND NET INFILTRATION RATE IN SURFICIAL SOILS AND ROCKS COVERING YUCCA MOUNTAIN

0 TO CHARACTERIZE INFILTRATION PROCESSES UNDER SIMULATED WETTER CONDITIONS IN THE SURFICIAL SOILS AND ROCKS COVERING YUCCA MOUNTAIN
REVIEW OF NWTRB MEETING – DECEMBER 11TH, 1989, DENVER

OUTLINE

- CONCEPTUAL MODEL

CHARACTERIZATION OF SURFICIAL MATERIALS

- OVERVIEW OF THE YUCCA MOUNTAIN AREA
- CURRENT AND FUTURE WORK

CHARACTERIZATION OF NATURAL INFILTRATION

- REGIONAL ESTIMATE OF RECHARGE
- LOCAL ESTIMATE OF RECHARGE
- PAGANY WASH STUDY

CHARACTERIZATION OF ARTIFICIAL INFILTRATION

- ARTIFICIAL INFILTRATION CONTROL PLOT STUDIES

VARIABLE INFILTRATION INPUT TO PA/SITE MODEL

- HOURLY TO THOUSAND YEAR EVENTS

SUMMARY
CHARACTERIZATION OF UNSATURATED ZONE INFILTRATION

METHODS

- CHARACTERIZATION OF SURFICIAL MATERIALS
  - PHYSICAL AND HYDROLOGIC PROPERTIES
  - SURFACE AND BOREHOLE GEOPHYSICS
  - MAPPING (GIS)

- CHARACTERIZATION OF NATURAL INFILTRATION
  - PRECIPITATION
  - EVAPOTRANSPIRATION
  - NEUTRON LOGGING
  - GEMOCHEMISTRY
    * TRITIUM
    * DEL 18O/DEL 2H
    * 14C, PMC

- CHARACTERIZATION OF ARTIFICIAL INFILTRATION
  - INFILTROMETER STUDY
  - SMALL PLOT RAINFALL SIMULATION
  - LARGE PLOT RAINFALL SIMULATION
  - PONDING
"A SENSIBLE PHILOSOPHY CONTROLLED BY A RELEVANT SET OF CONCEPTS SAVES SO MUCH RESEARCH TIME THAT IT CAN NEARLY ACT AS A SUBSTITUTE FOR GENIUS."

N. W. PIRIE, CONCEPTS OUT OF CONTEXT
GENERALIZED TOPOGRAPHIC SETTINGS
AND HYDROGEOLOGIC CONDITIONS

RIDGE/SLOPE

UPLAND DRAINAGE CHANNEL

UPLAND CHANNEL

LOWER CANYON WALL

TERRACE

RECENT CHANNEL

OLD CHANNEL

BOREHOLES

MORE WELDED

MORE MODERATELY &/OR DENSELY WELDED
MORE FRACTURED

LESS WELDED

BEDDED/NON-WELDED &/OR PARTIALLY WELDED
MORE POROUS
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SUMMARY
"I GET IT", SAID LEORA, "YOUR JOB WILL ONLY TAKE ABOUT 28 HOURS A DAY, THE REST OF THE TIME YOU'RE PERFECTLY WELCOME TO SPEND ON RESEARCH, UNLESS, OF COURSE, SOMEBODY INTERRUPTS YOU."

SINCLAIR LEWIS, ARROWSMITH
INTRODUCTION OF COLOR MAP OF YUCCA MOUNTAIN
<table>
<thead>
<tr>
<th></th>
<th>MEAN</th>
<th>STD DEV</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobbles (%) &gt; 75mm</td>
<td>15.3</td>
<td>8.29</td>
<td>54.5</td>
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<tr>
<td>Clay (%)</td>
<td>13.2</td>
<td>4.66</td>
<td>35.4</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>26.1</td>
<td>5.18</td>
<td>19.9</td>
</tr>
<tr>
<td>Sand (%)</td>
<td>60.8</td>
<td>5.38</td>
<td>8.9</td>
</tr>
<tr>
<td>Fine soil &lt;2mm</td>
<td>1.24</td>
<td>0.086</td>
<td>7.0</td>
</tr>
<tr>
<td>Total soil</td>
<td>1.56</td>
<td>0.087</td>
<td>5.6</td>
</tr>
</tbody>
</table>

| K sat (cm/s) | $5.7 \times 10^{-4}$ | $2.2 \times 10^{-5}$ | 3.8 |

1 From Schmidt, M.R., A.L. Flint, and K. Kolm (199X)
2 Estimate based on Campbell (1985)
MOISTURE RETENTION OF ALLUVIUM USING THERMOCOUPLE PSYCHROMETRY

BROOKS AND COREY MODEL

\[ \text{WATER POTENTIAL} = 0.05(\text{WATER CONTENT})^{-1.275} \]

\[ r^2 = 0.84 \]

DISTURBED FIELD SAMPLES APPROX. 1 CM$^3$
## PAGANY WASH TRANSECT

<table>
<thead>
<tr>
<th>UNIT</th>
<th>% OF UNIT IN TRANSECT</th>
<th>% OF UNIT EXPOSED</th>
<th>FRACTURE DENSITY (F/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caprock</td>
<td>12</td>
<td>13</td>
<td>1.3</td>
</tr>
<tr>
<td>Upper Cliff</td>
<td>16</td>
<td>11.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Upper Lithophysal</td>
<td>27</td>
<td>24</td>
<td>1.1</td>
</tr>
<tr>
<td>Rounded Step</td>
<td>22.5</td>
<td>24</td>
<td>1.8</td>
</tr>
<tr>
<td>Lower Lithophysal</td>
<td>12</td>
<td>18.5</td>
<td>2.8</td>
</tr>
<tr>
<td>Hackly</td>
<td>5.5</td>
<td>5.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Columnar</td>
<td>5</td>
<td>12.5</td>
<td>0.3</td>
</tr>
</tbody>
</table>

*Alluvium 18% of transect.*

---

### CROSS SECTION AT N-10

**NOT TO SCALE**
<table>
<thead>
<tr>
<th>UNIT</th>
<th>% OF UNIT IN TRANSECT</th>
<th>% OF UNIT EXPOSED</th>
<th>FRACTURE DENSITY (F/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caprock</td>
<td>3</td>
<td>4.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Upper Cliff</td>
<td>21</td>
<td>29.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Upper Lithophysal</td>
<td>28.5</td>
<td>18.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Clinkstone</td>
<td>8</td>
<td>6.5</td>
<td>0.7</td>
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<tr>
<td>Middle Lithophysal</td>
<td>15.5</td>
<td>18</td>
<td>0.8</td>
</tr>
<tr>
<td>Rounded Step</td>
<td>10.5</td>
<td>10</td>
<td>1.8</td>
</tr>
<tr>
<td>Lower Lithophysal</td>
<td>5.5</td>
<td>4</td>
<td>1.0</td>
</tr>
<tr>
<td>Hackly</td>
<td>8</td>
<td>9</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Alluvium 22% of transect.
<table>
<thead>
<tr>
<th>Geologic Map Unit</th>
<th>Welding</th>
<th>% of Area Exposed</th>
<th>Exposed Density (Fx/m)</th>
<th>% of Area Fracture</th>
<th>Exposed Density (Fx/m)</th>
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</thead>
<tbody>
<tr>
<td>Paintbrush Tuff</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Tiva Canyon Member</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caprock</td>
<td>M</td>
<td>11.3</td>
<td>2.7</td>
<td>1.0</td>
<td>0.7</td>
</tr>
<tr>
<td>Upper Cliff</td>
<td>M</td>
<td>4.2</td>
<td>0.3</td>
<td>0.7</td>
<td>8.6</td>
</tr>
<tr>
<td>Upper Lithophysal</td>
<td>D</td>
<td>13.4</td>
<td>26.9</td>
<td>3.6</td>
<td>31.1</td>
</tr>
<tr>
<td>Clinkstone</td>
<td>D</td>
<td>4.1</td>
<td>8.2</td>
<td>0.3</td>
<td>14.7</td>
</tr>
<tr>
<td>Rounded Step</td>
<td>D</td>
<td>4.5</td>
<td>8.9</td>
<td>0.4</td>
<td>14.6</td>
</tr>
<tr>
<td>Lower Lithophysal</td>
<td>D</td>
<td>3.0</td>
<td>6.0</td>
<td>0.2</td>
<td>9.4</td>
</tr>
<tr>
<td>Hackly</td>
<td>D</td>
<td>2.9</td>
<td>5.7</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Columnar</td>
<td>D</td>
<td>1.7</td>
<td>3.2</td>
<td>0.1</td>
<td>0.8</td>
</tr>
<tr>
<td>Yucca Mountain Member</td>
<td>N-M</td>
<td>1.6</td>
<td>3.0</td>
<td>&lt;0.1</td>
<td>1.0</td>
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<tr>
<td>Pah Canyon Member</td>
<td>N-M</td>
<td>1.0</td>
<td>1.8</td>
<td>&lt;0.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Topopah Spring Member</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undifferentiated</td>
<td>N</td>
<td>0.4</td>
<td>0.7</td>
<td>&lt;0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Caprock</td>
<td>M</td>
<td>0.1</td>
<td>0.1</td>
<td>&lt;0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Bedded/Reworked Tuffs</td>
<td>N</td>
<td>1.7</td>
<td>3.5</td>
<td>0.1</td>
<td>1.6</td>
</tr>
<tr>
<td>Alluvium/Colluvium</td>
<td></td>
<td>50.1</td>
<td>0</td>
<td>10.9</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Bedrock</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>49.9</td>
<td></td>
<td></td>
<td>89.1</td>
</tr>
<tr>
<td><strong>Total Exposed Bedrock</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17.7</td>
</tr>
</tbody>
</table>
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SUMMARY
CURRENT AND FUTURE WORK

- Sampling, test and mapping of physical and hydrologic properties (current work)
  - Alluvium
  - Soil cover
  - Surface and subsurface bedrock

- Estimate of surficial units for 3-D hydrologic flow model (current work)

- Vertical variability (current and future work)
  - Inverse modeling for hydrologic properties (current work)
  - Measurements from neutron hole cores (future work)

- Soil thickness map (current and future work)
  - Borehole contacts (current work)
  - Surface geophysics (future work)
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SUMMARY
EXPLANATION

- Study Area 1
- Study Area 2, Fortymile Canyon Watershed
- Study Area 3, Upper Amargosa River Watershed
- Study Area 4, 150 km Radius

Isohyets are in millimeters.

Nevada State Plane Coordinate System, Central Zone
MAXEY-EAKIN AVE. ANNUAL INFILTRATION (MM): KRIGED A.A.P.
COKRIGED PRECIPITATION ESTIMATE FOR THE
UPPER AMARGOSA RIVER WATERSHED

EXPLANATION

Yucca Mountain Upland Area
Upper Amargosa River Watershed

ISOHYETS ARE IN MILLIMETERS

Nevada State Plane Coordinate System, Central Zone
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SUMMARY
3D FLOW MODEL SURFICIAL BOUNDARIES

NORTHING (FEET X 1000)

EASTING (FEET X 1000)

- RIDGE TOPS
- SIDE SLOPES
- ALLUVIUM
- REPOSITORY BOUNDARY
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SUMMARY
PAGANY WASH NEUTRON HOLES

- N7 CHANNEL UPSTREAM
- N13 CHANNEL DOWNSTREAM
- N9 TERRACE UPSTREAM
- N14 TERRACE DOWNSTREAM
- JAN. 1 OF EACH YEAR

TOP METER

VOLUMETRIC WATER CONTENT

1 - 5 METERS

5 - 10 METERS

DAYS SINCE 1/1/84
PHOTOGRAPH OF CLASS A EVAPORATION PAN
1990 CLASS A PAN EVAPORATION

AVERAGE EVAPORATION RATE, 0.7 (mm/day)

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
PHOTOGRAPH OF BOWEN RATIO
EVAPOTRANSPIRATION STATION IN PAGANY WASH
PHOTOGRAPHS OF VEGETATION IN DRILL HOLE WASH IN 1984 FOLLOWING SEVERAL WET YEARS, IN 1990 FOLLOWING 5 YEARS OF DROUGHT, AND IN 1991 FOLLOWING ONE WET SPRING
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SUMMARY
PHOTOGRAPH OF TEST CELL "C" INFILTRATION TEST PLOT
PHOTOGRAPH OF TOPOPAH WASH BOREHOLE INSTRUMENTATION
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SUMMARY
CYCLES OF PRECIPITATION INPUT FOR NET INFILTRATION

- **Positive Net Infiltration**
- **Average Annual Precipitation**
- **Negative Net Infiltration**

**Precipitation, mm/day**

**Time**
SUMMARY

- CURRENT UNDERSTANDING OF PROCESSES IS REQUIRED

- DEFINE CHARACTER OF UPPER FLUX BOUNDARY CONDITIONS
  - DEVELOP CONCEPTUAL MODEL AND ALTERNATIVES
  - DEVELOP SAMPLING AND MEASUREMENT SCHEME
  - COLLECT AND ANALYZE DATA
  - ITERATE

- DESIGN MODELS FOR CURRENT AND FUTURE CLIMATIC CONDITIONS