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

DECEMBER 11-12, 1989

CHARACTERIZATION OF UNSATURATED ZONE INFILTRATION

- **OBJECTIVE**
  - DEFINE THE UPPER FLUX BOUNDARY CONDITIONS OF YUCCA MOUNTAIN UNDER PRESENT DAY AND SIMULATED WETTER CLIMATIC CONDITIONS

CHARACTERIZATION OF UNSATURATED ZONE INFILTRATION

METHODS

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

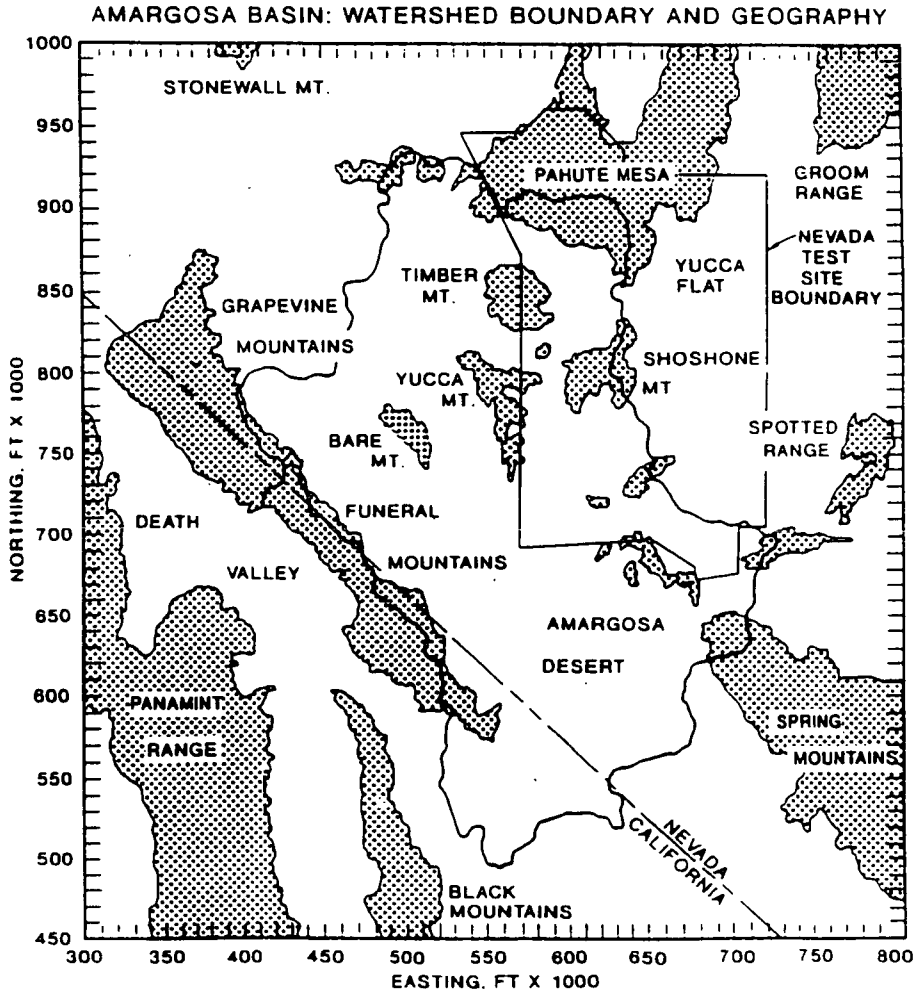
- **CHARACTERIZATION OF NATURAL INFILTRATION**
  - PRECIPITATION
  - EVAPOTRANSPIRATION
  - NEUTRON LOGGING
  - GEOCHEMISTRY
    - * TRITIUM
    - * DEL ^{18}O/DEL ^{2}H
    - * ^{14}C, PMC

- **CHARACTERIZATION OF ARTIFICIAL INFILTRATION**
  - INFILTROMETER STUDY
  - SMALL PLOT RAINFALL SIMULATION
  - LARGE PLOT RAINFALL SIMULATION
  - PONDING

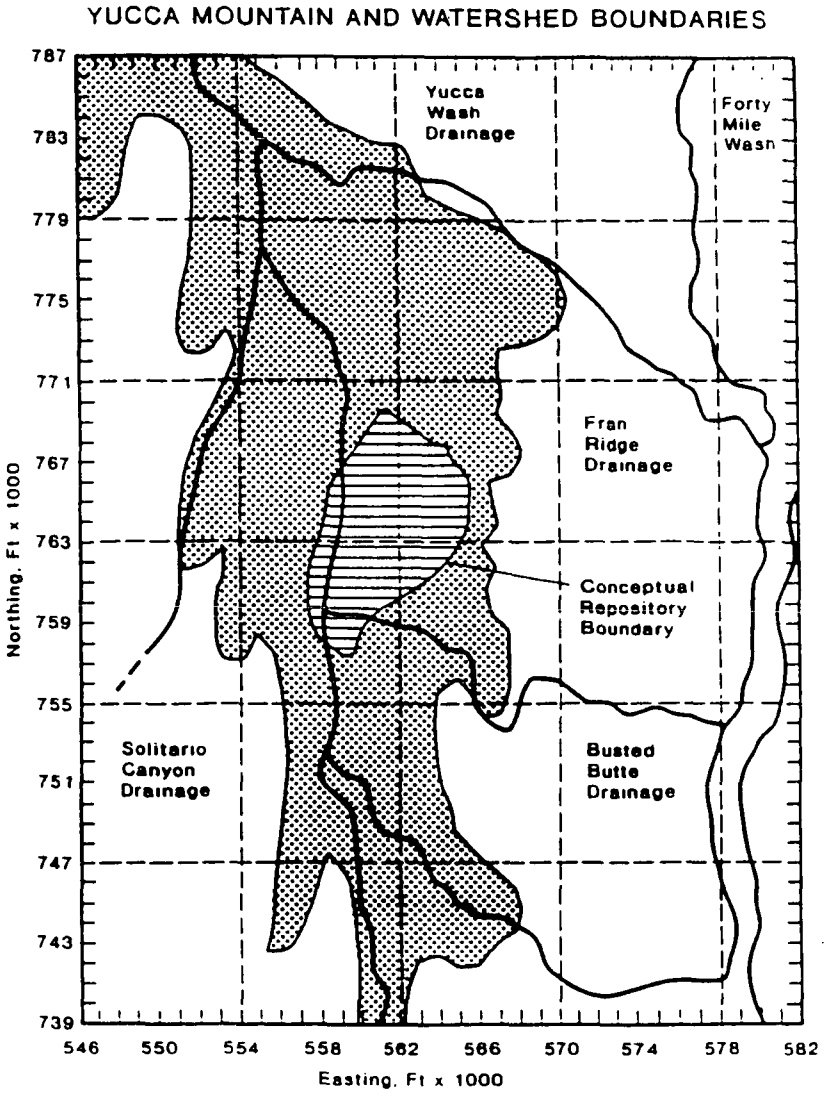
AREAS OF INTEREST

- **LARGE SCALE**
  - THE UPPER AMARGOSA RIVER WATERSHED
- **INTERMEDIATE SCALE**
  - YUCCA WASH AND FORTYMILE WASH WATERSHEDS
- **SMALL SCALE**
  - SMALLEST DEFINABLE WATERSHED UNIT AREALLY OVER REPOSITORY AREA

WATERSHED BOUNDARY AND GEOGRAPHY OF AMARGOSA BASIN, INCLUDING YUCCA MOUNTAIN AND NEVADA TEST SITE BOUNDARIES



WATERSHED BOUNDARIES FOR 5 DRAINAGES ON YUCCA MOUNTAIN



INFILTRATION PROGRAM

- **INFILTRATION**
  - DOWNWARD MOVEMENT OF WATER ACROSS AIR-SOIL INTERFACE
- **PERCOLATION**
  - DOWNWARD MOVEMENT OF INFILTRATION WATER
- **NET INFILTRATION**
  - PERCOLATED WATER THAT HAS MOVED BELOW THE ZONE OF EVAPOTRANSPIRATION (ZERO FLUX PLANE)

INFILTRATION PROGRAM

(CONTINUED)

WATER BALANCE APPROACH

- NET INFILTRATION =

  PRECIPITATION - EVAPORATION - RUNOFF +/- CHANGE IN STORAGE

- FRAMEWORK TO EVALUATE COMPONENT PARTS

CONCEPTUAL MODEL

- NET INFILTRATION IS SPATIALLY AND TEMPORALLY VARIABLE
- WATER BALANCE APPROACH IS USED AS A FRAMEWORK BUT NOT SOLVED SPECIFICALLY FOR NET INFILTRATION

CONCEPTUAL MODEL OF INFILTRATION

TOPOGRAPHIC SETTINGS AND HYDROGEOLOGIC CONDITIONS

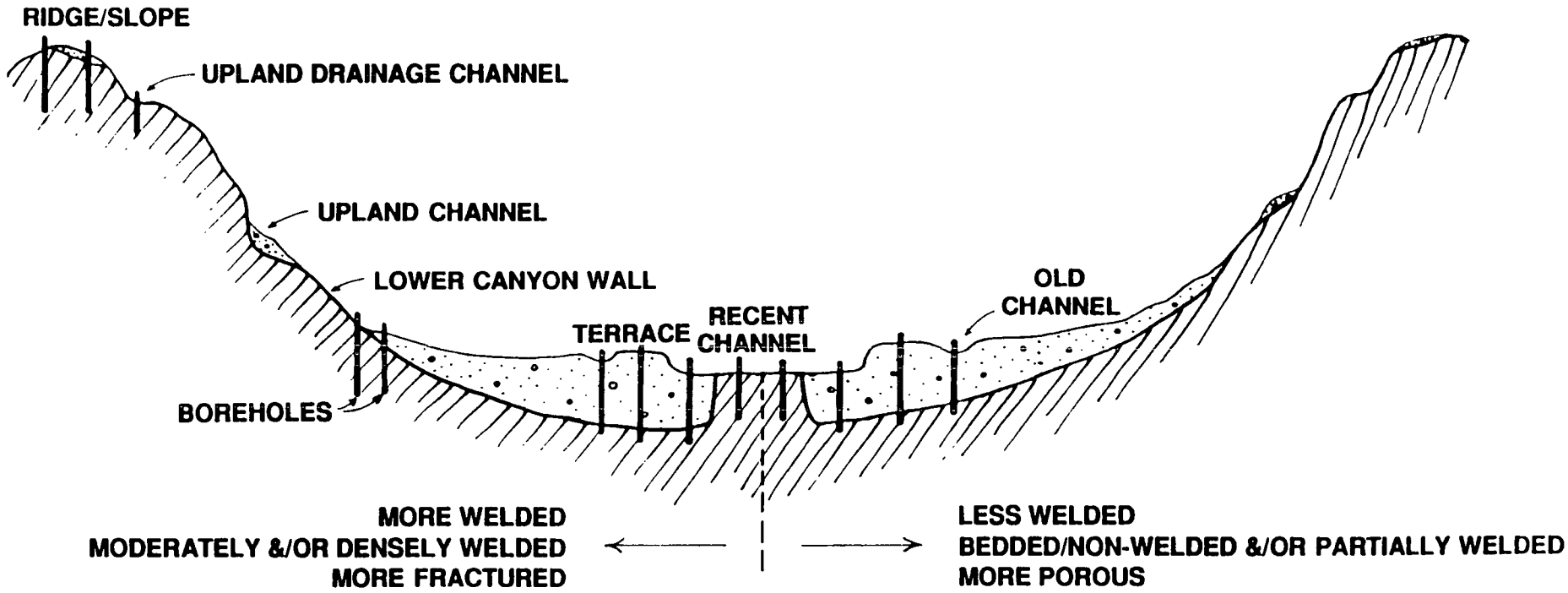
- RIDGE/SLOPE
- UPLAND BEDROCK CHANNEL
- UPLAND ALLUVIAL CHANNEL
- LOWER CANYON WALL
- OLD CHANNEL
- TERRACE
- RECENT CHANNEL
- RECENT CHANNEL WITH BEDROCK EXPOSURE

CONCEPTUAL MODEL OF INFILTRATION

MECHANISMS

- PRECIPITATION
- SURFACE RUNOFF
- INFILTRATION
- MATRIX FLOW IN ALLUVIUM AND ROCK
- FRACTURE FLOW IN ALLUVIUM AND ROCK
- EVAPOTRANSPIRATION
- RECHARGE?

GENERALIZED TOPOGRAPHIC SETTINGS GENERALIZED HYDROGEOLOGIC CONDITIONS



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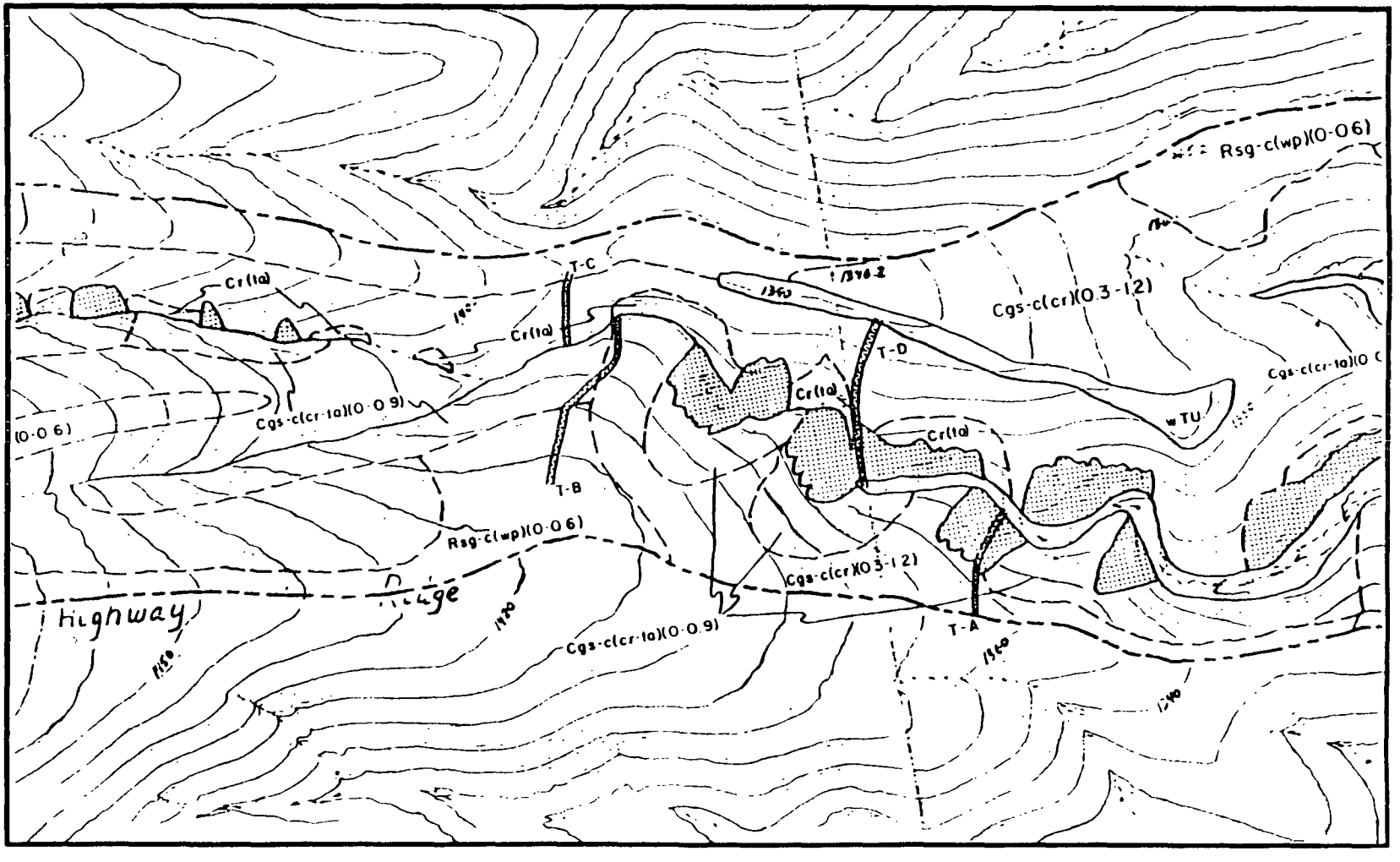
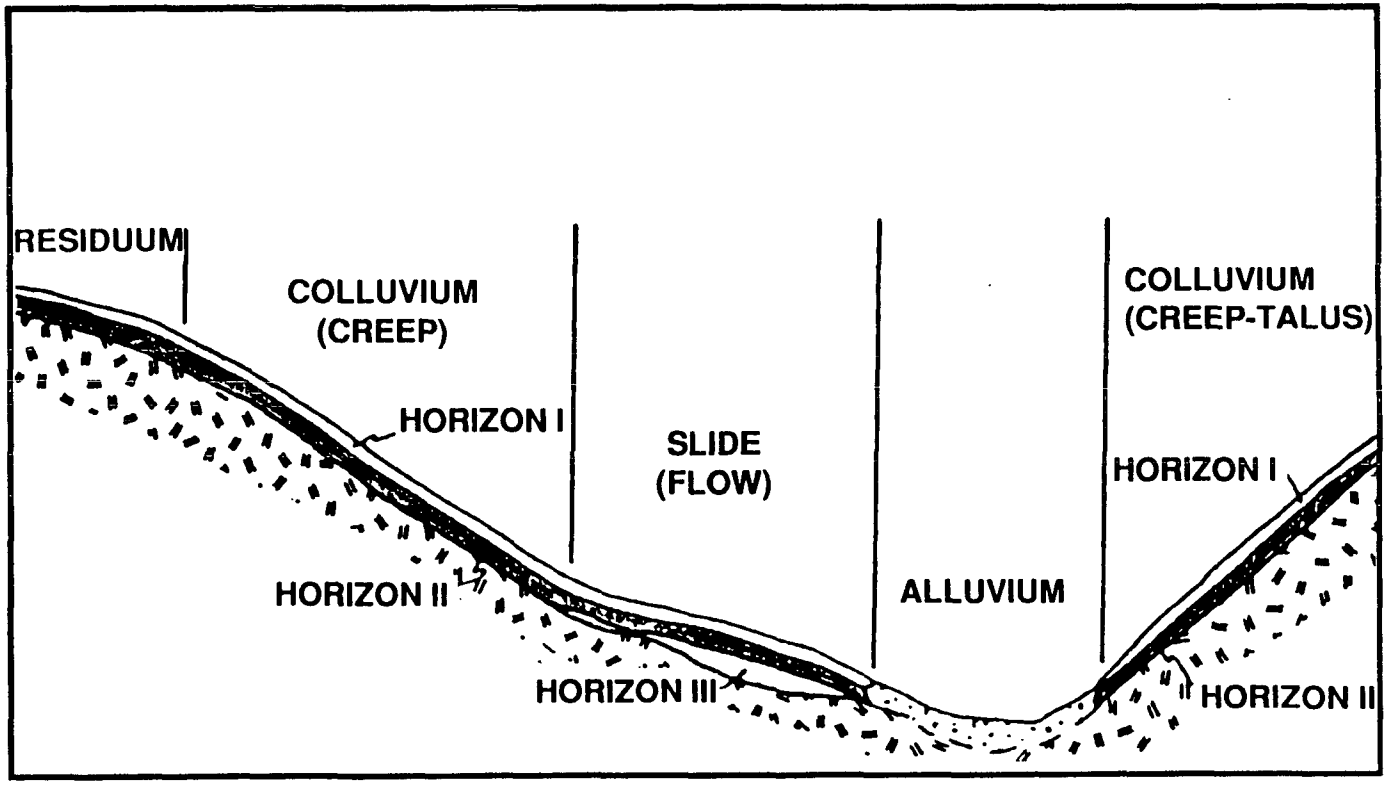
PHOTOGRAPH: AERIAL VIEW OF HIGHWAY RIDGE MAPPING PROJECT

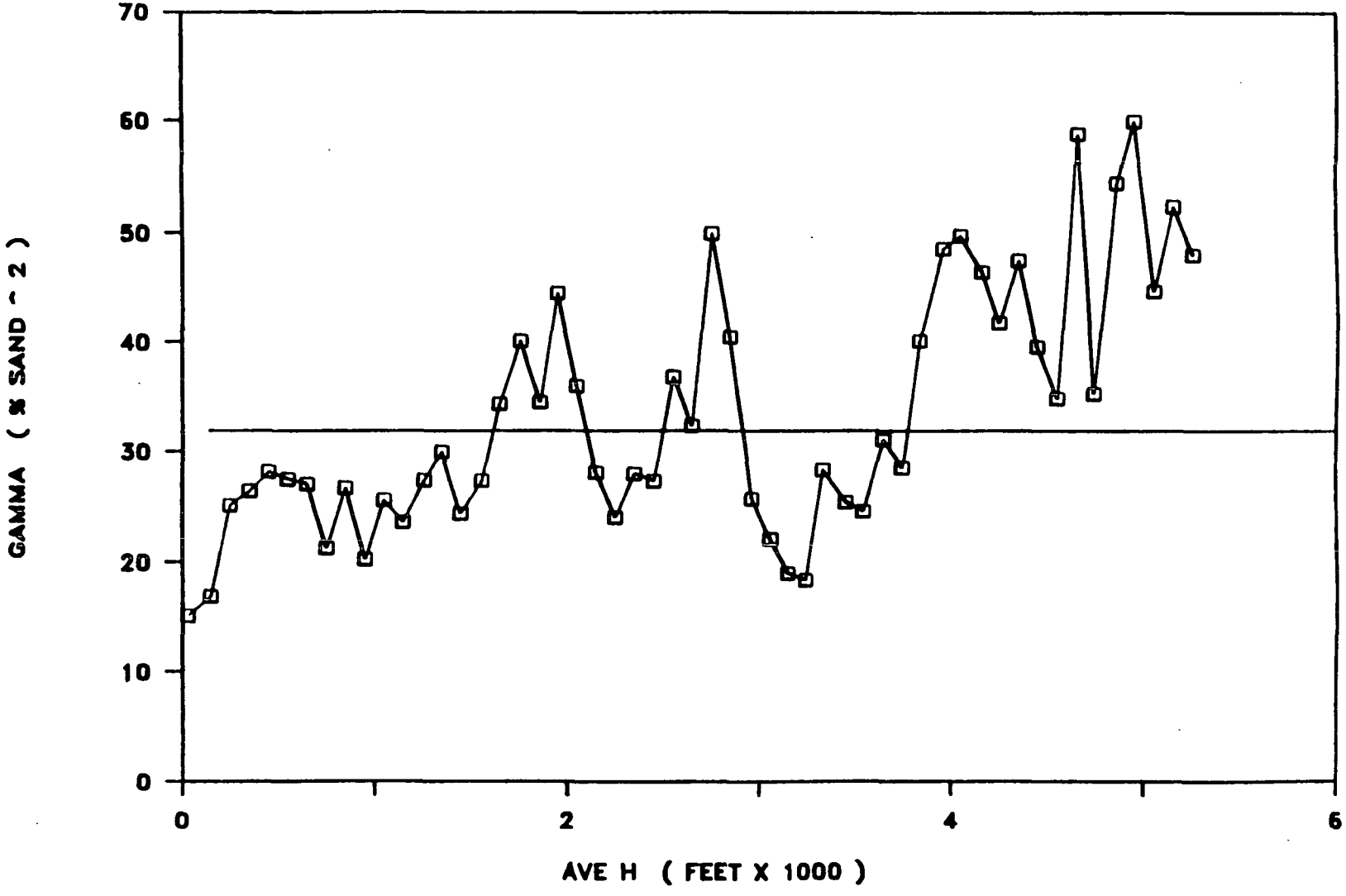
MAP OF SURFICIAL MATERIALS IN WASH - RIDGE SYSTEM NORTH OF HIGHWAY RIDGE



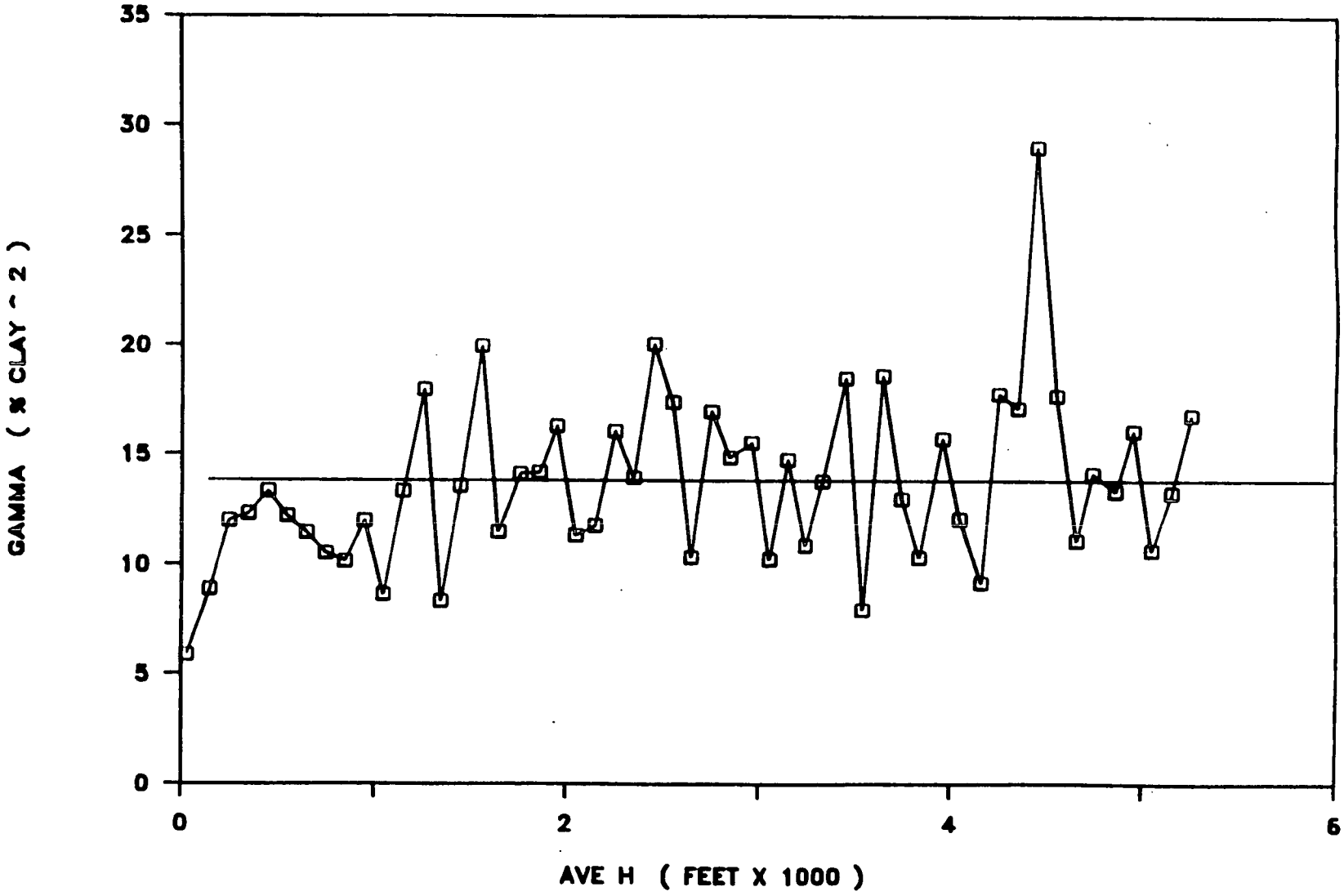
SCHEMATIC OF GEOMORPHOLOGIC UNITS (WASH NORTH OF HIGHWAY RIDGE)



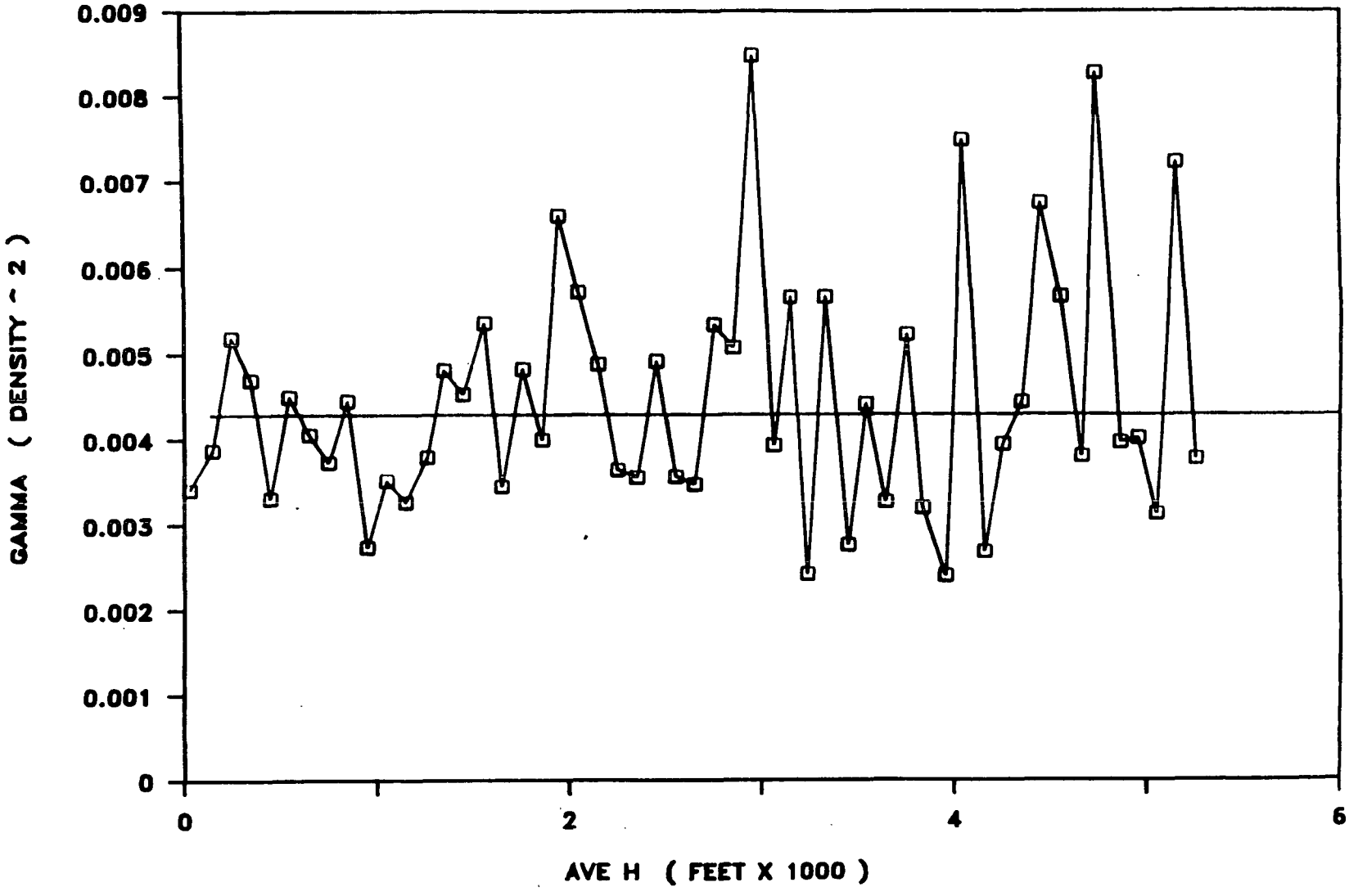
% SAND DIRECT VARIOGRAM



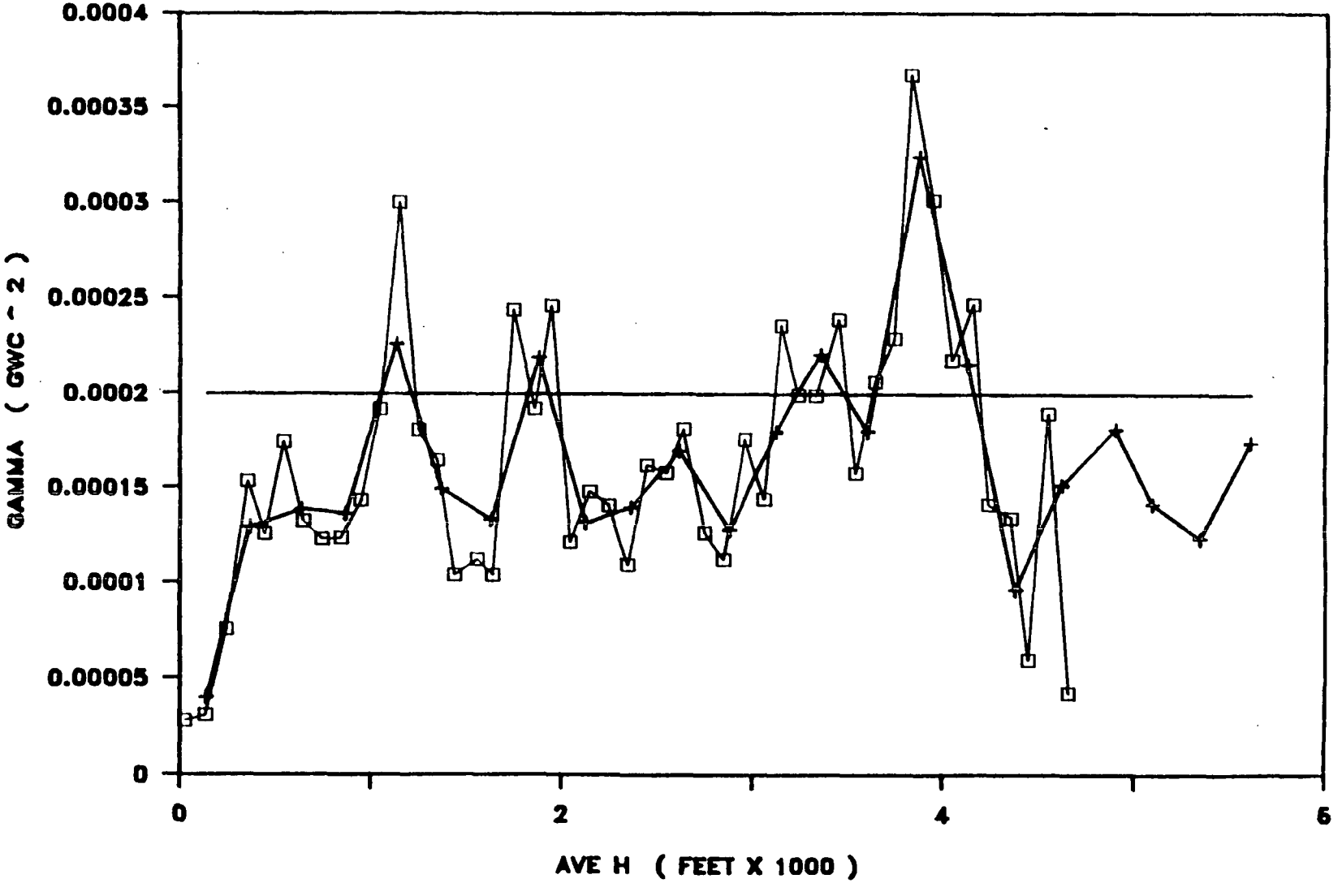
% CLAY DIRECT VARIOGRAMS



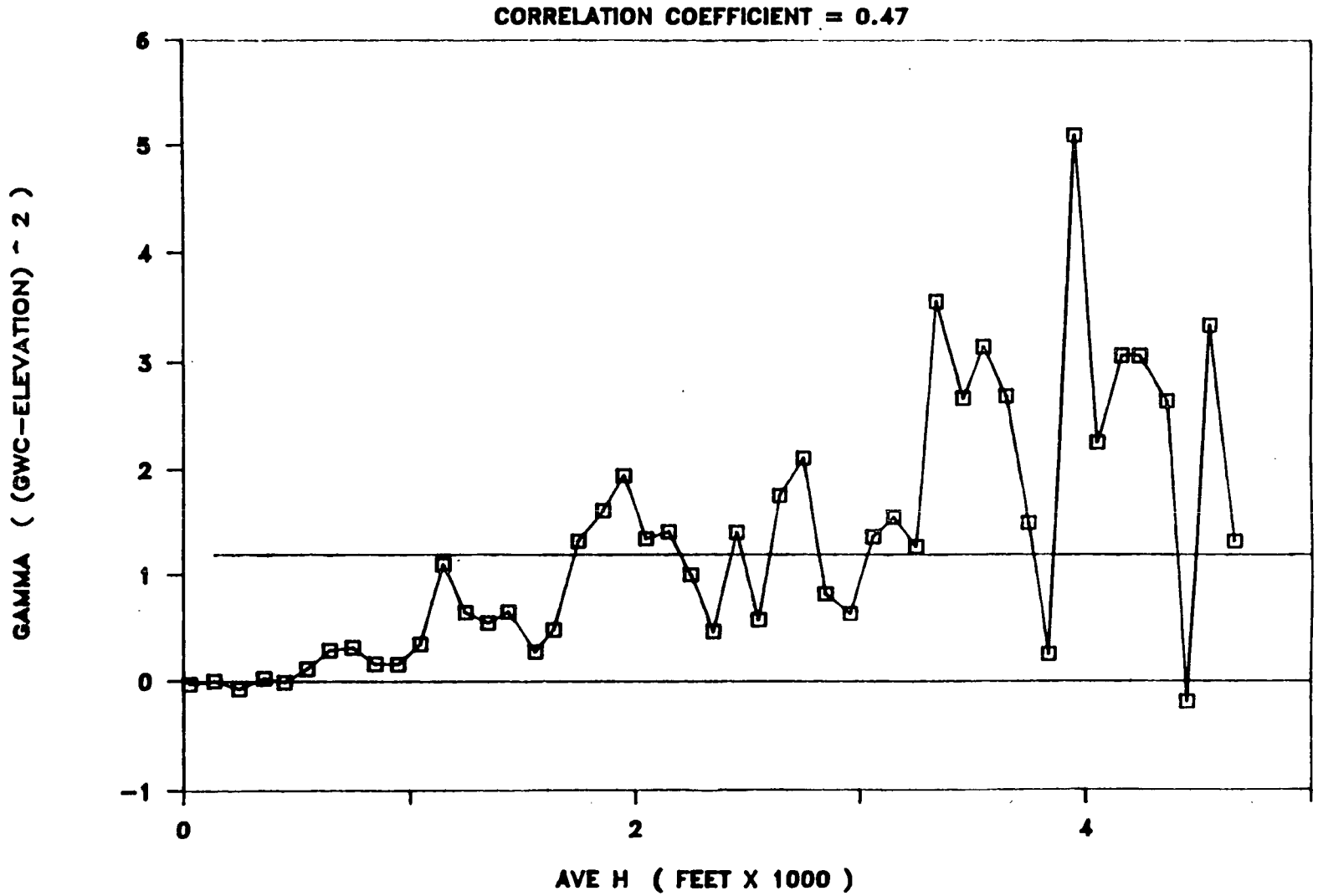
DRY BULK DENSITY DIRECT VARIOGRAMS



GRAVIMETRIC WATER CONTENT DIRECT VARIOGRAMS



G.W.C. - ELEVATION CROSS VARIOGRAM



SUMMARY OF SURFICIAL PROPERTIES

Soil Physical Properties	Mean	Standard Deviation	Coefficient of Variation	Range in Values	Number of Measurements
Cobbles (%) > 75mm	15.3	8.29	54.5	1.50 - 46.0	104
Clay (%)	13.2	4.66	35.4	3.0 - 27.1	126
Silt (%)	26.1	5.18	19.9	13.7 - 38.1	126
Sand (%)	60.8	5.38	8.86	43.5 - 71.6	126
BULK DENSITY (g/cm^3)					
Fine Soil < 2mm	1.24	0.0862	6.96	1.12 - 1.50	33
Total Soil	1.56	0.0872	5.57	1.34 - 1.72	32

From Schmidt, M.R., Flint, A.L., and Kolm, K., 1989

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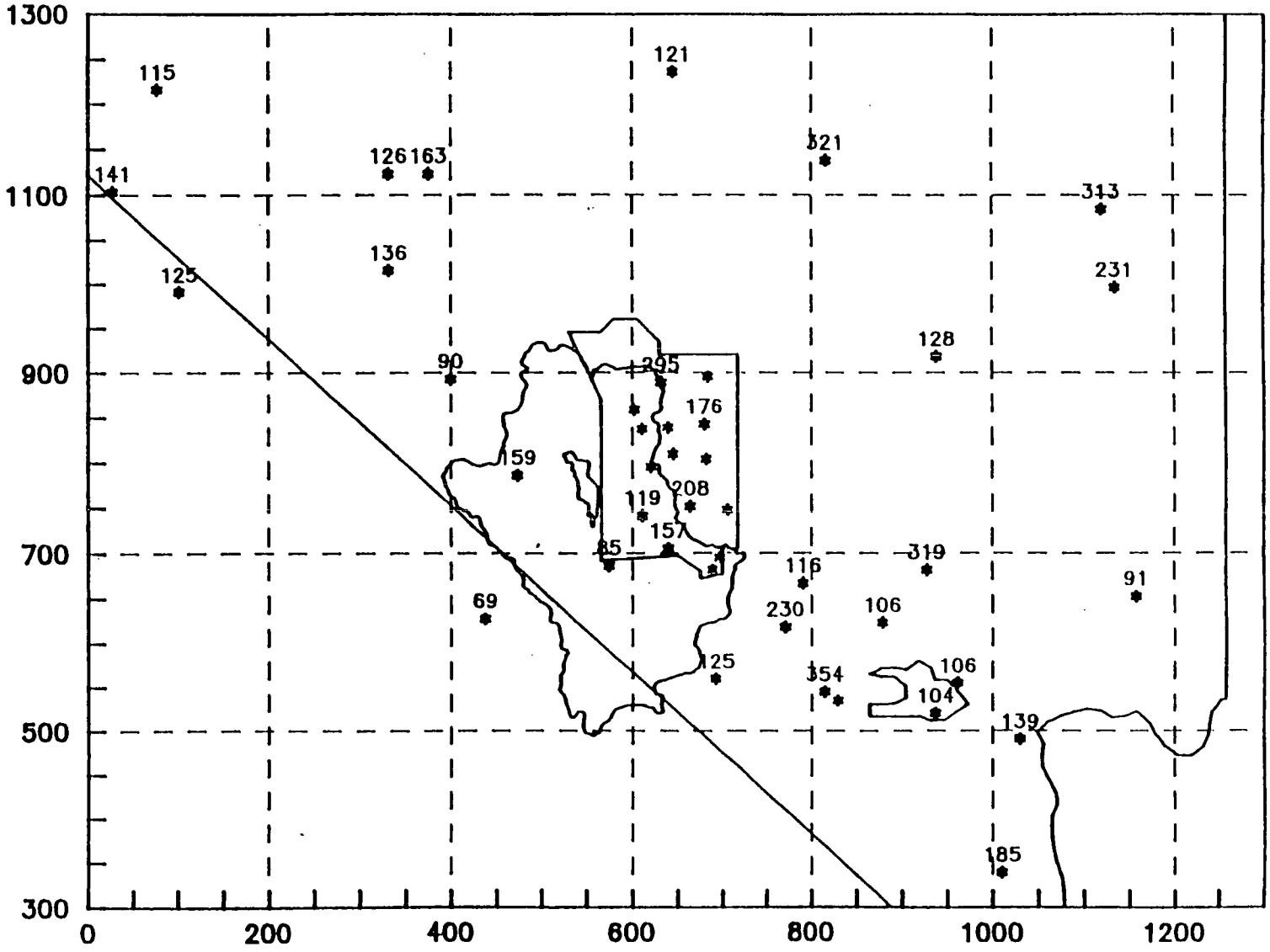
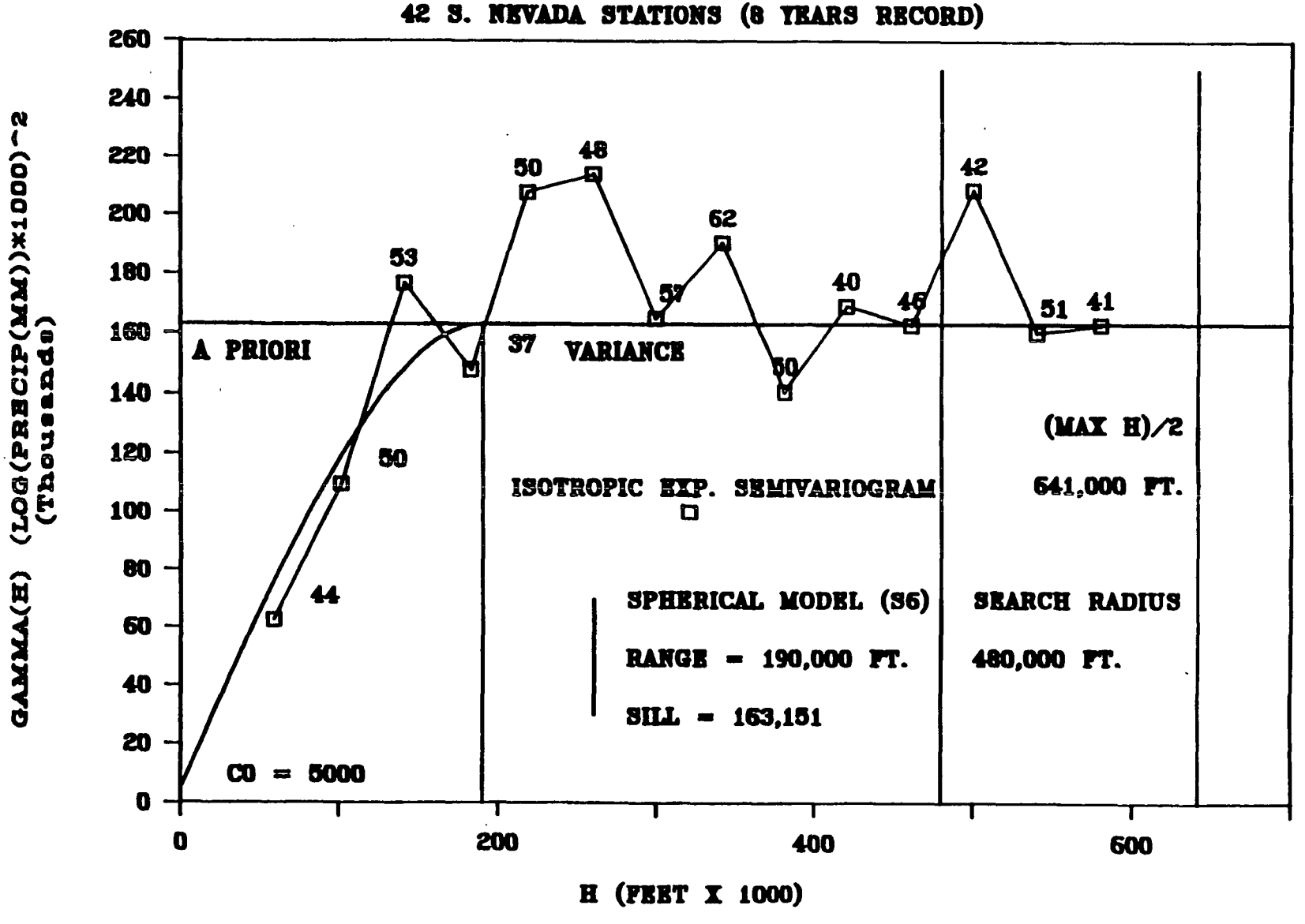
S. NEVADA PRECIPITATION STATION LOCATION (8 YEARS RECORD)



LOG(PREC(MM)) x 1000 DIRECT SEMIVARIOGRAM



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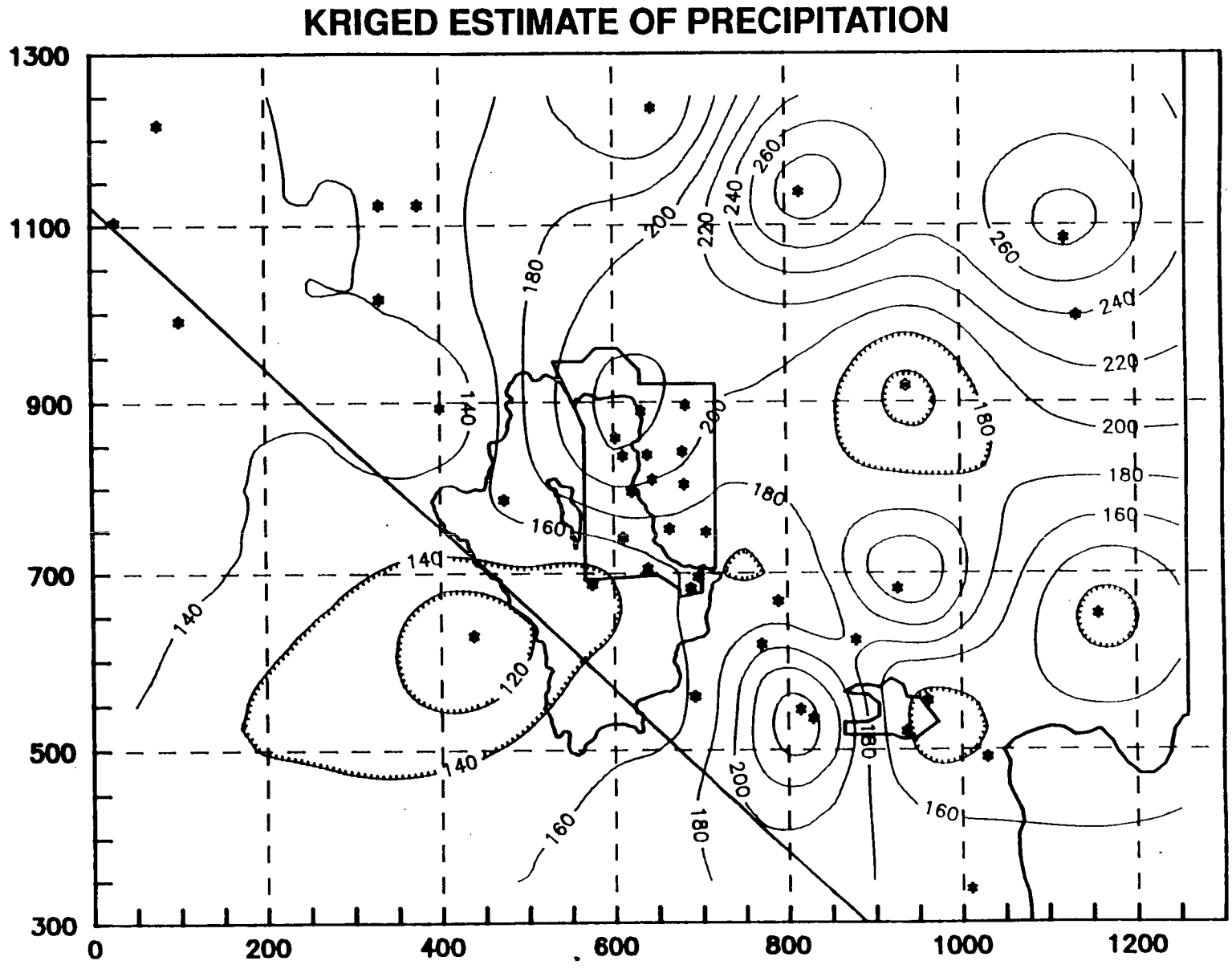
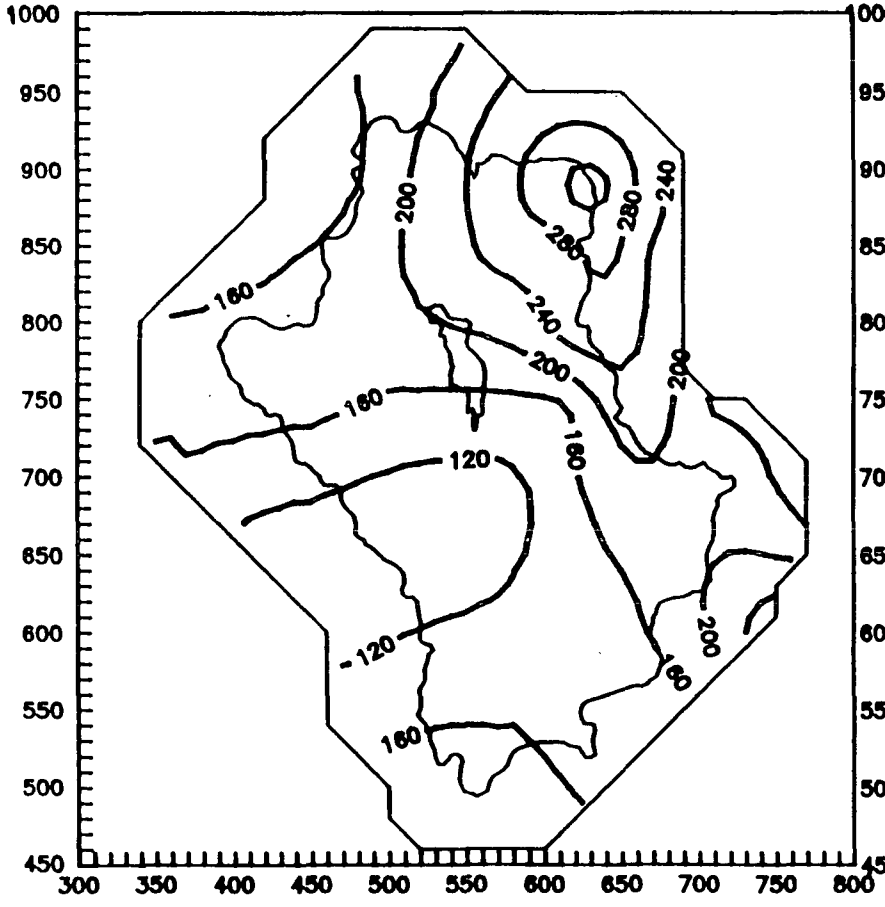
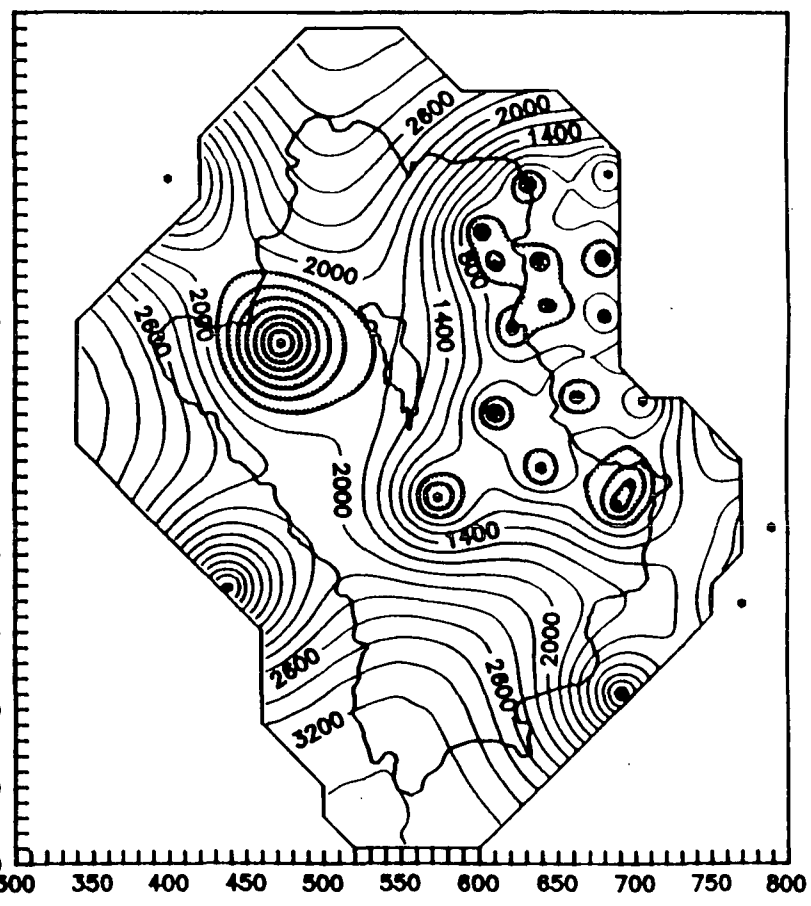


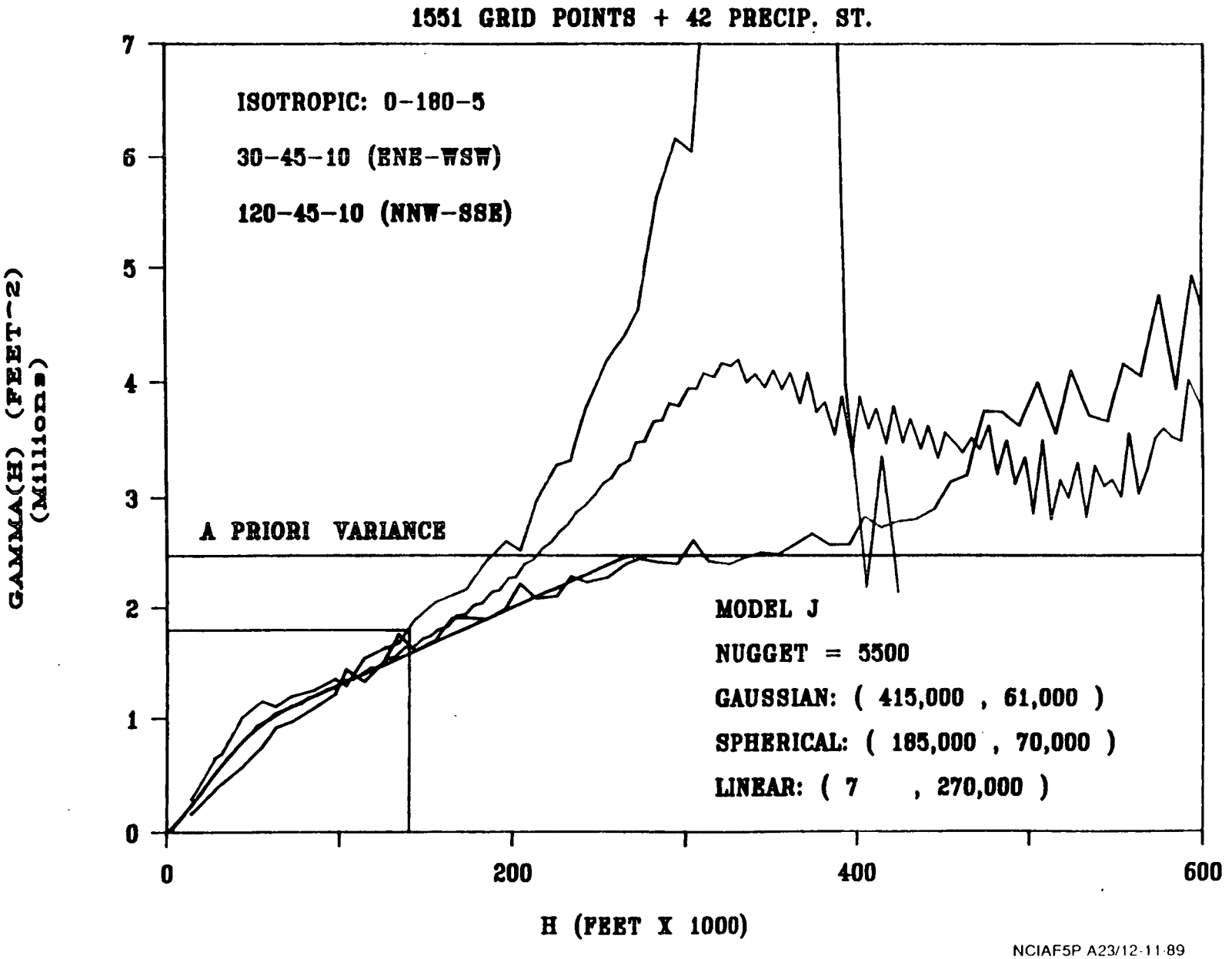
KRIGED PRECIPITATION (MM) MODEL S6



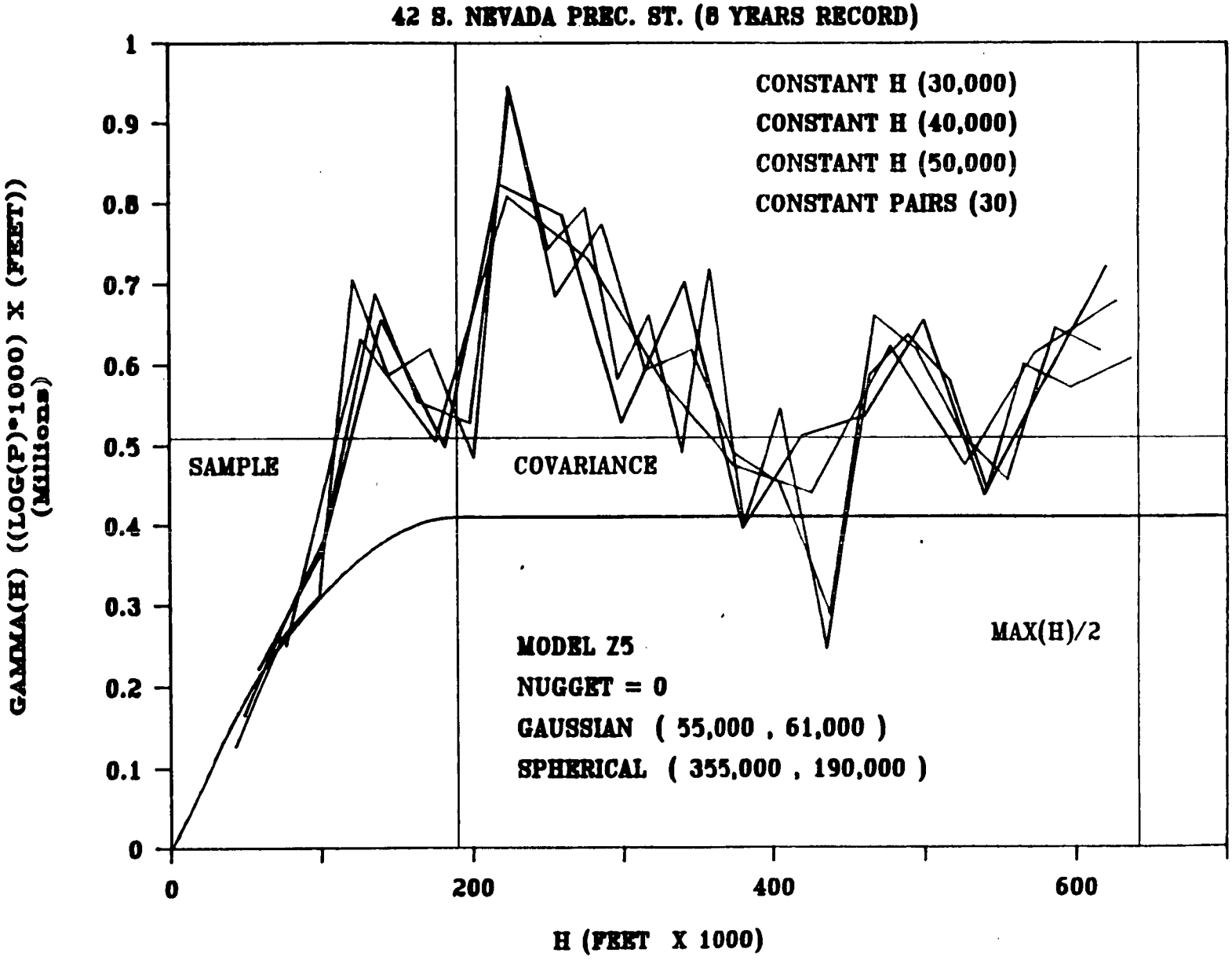
KRIGED VARIANCES (MM*MM)



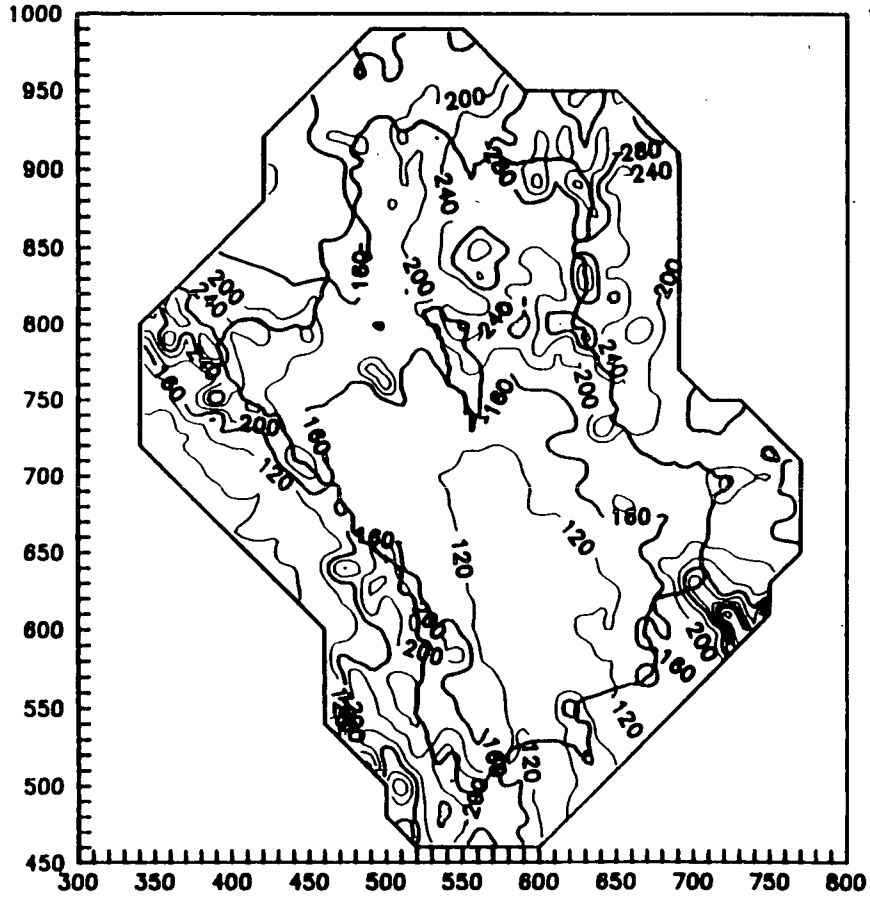
ELEVATION DIRECT SEMIVARIOGRAM



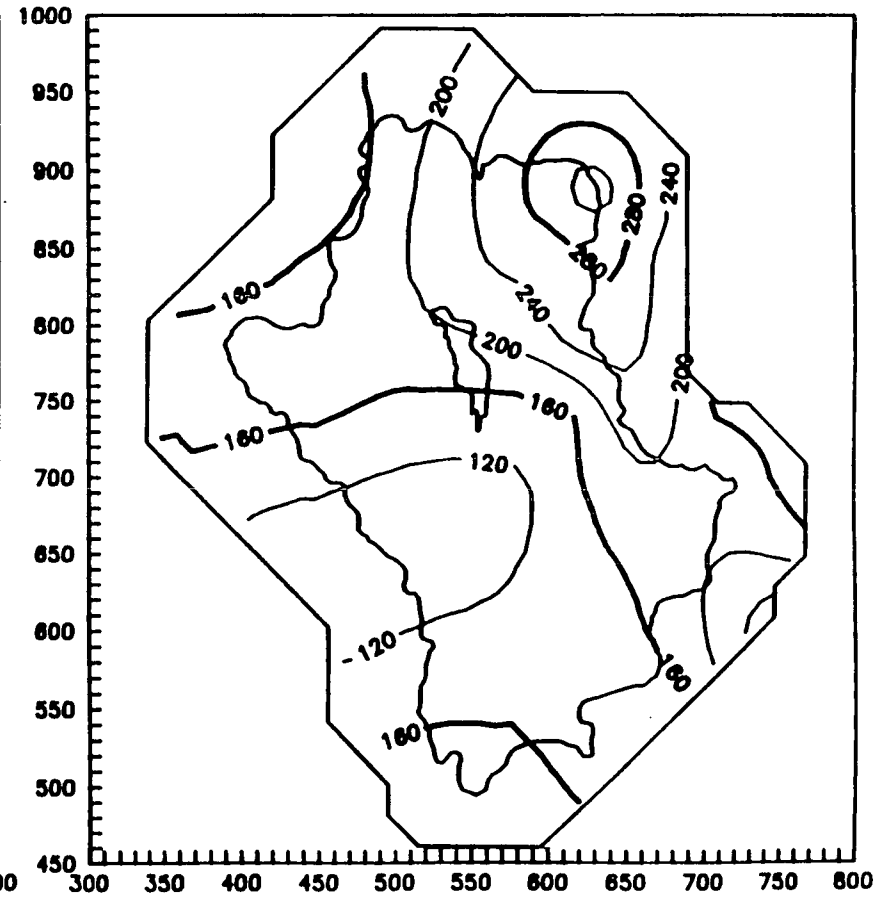
LOG(P)*1000 - ELEV. CROSS SEMIVARIOGRAM



COKRIGED PRECIP.(MM) MODEL Z5



KRIGED PRECIP. (MM) MODEL S6



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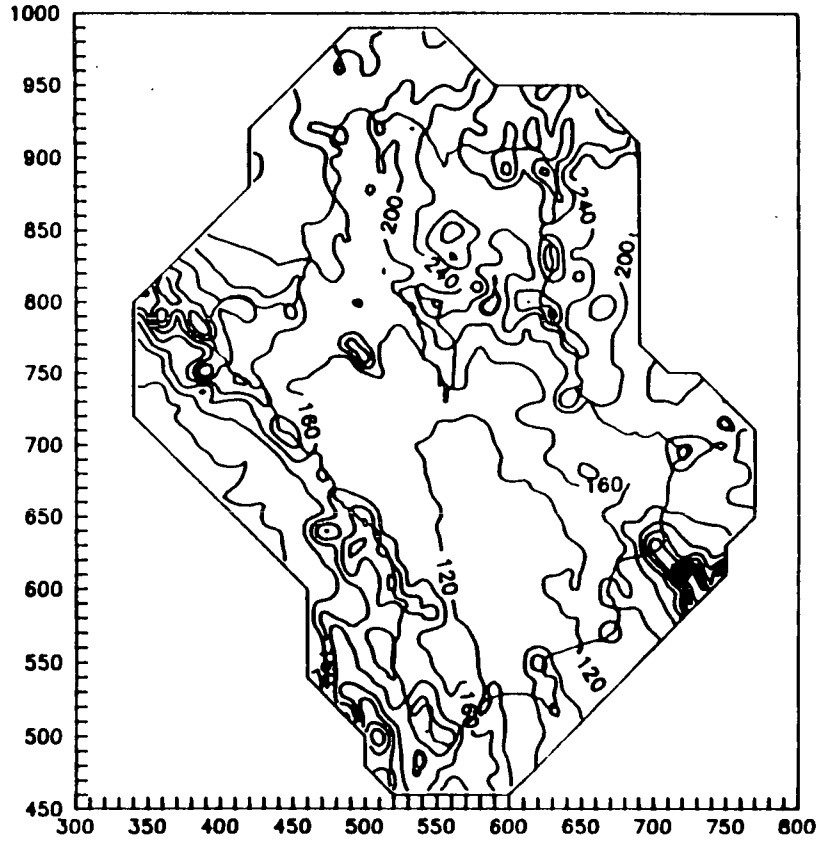
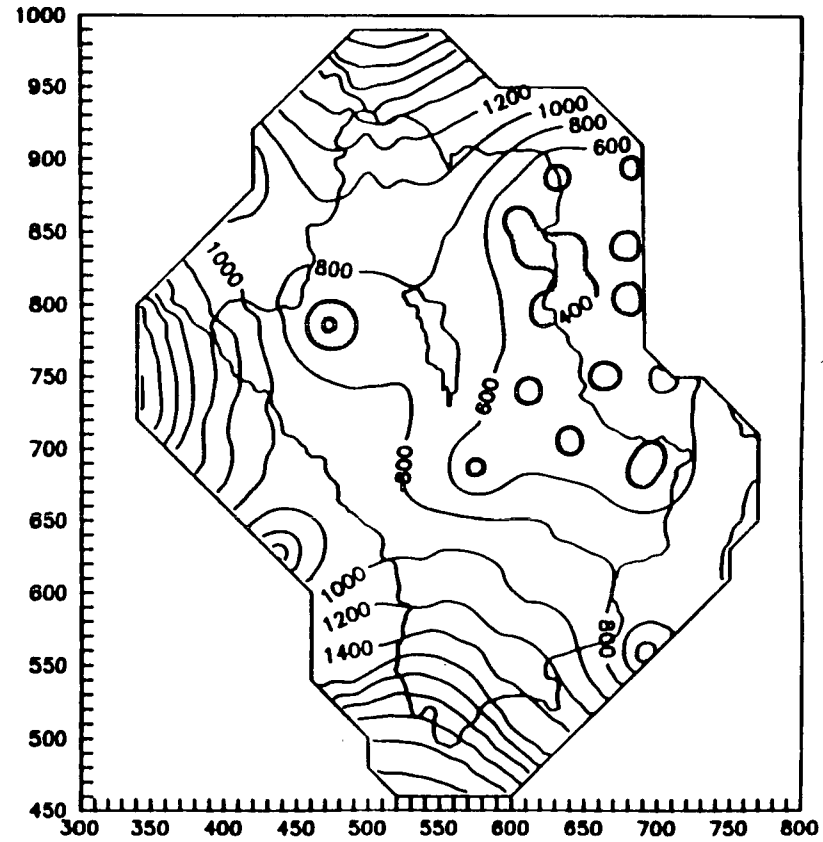
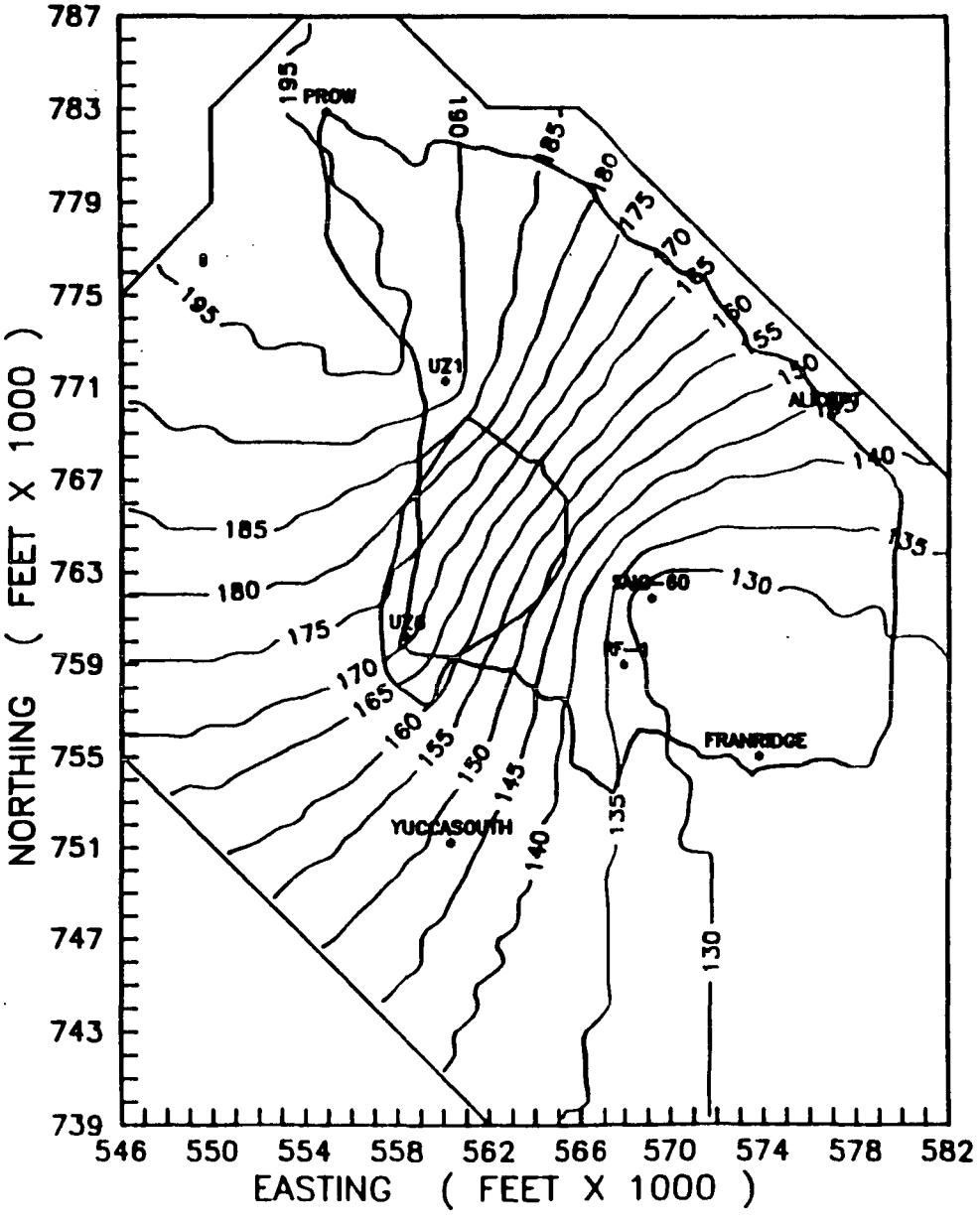


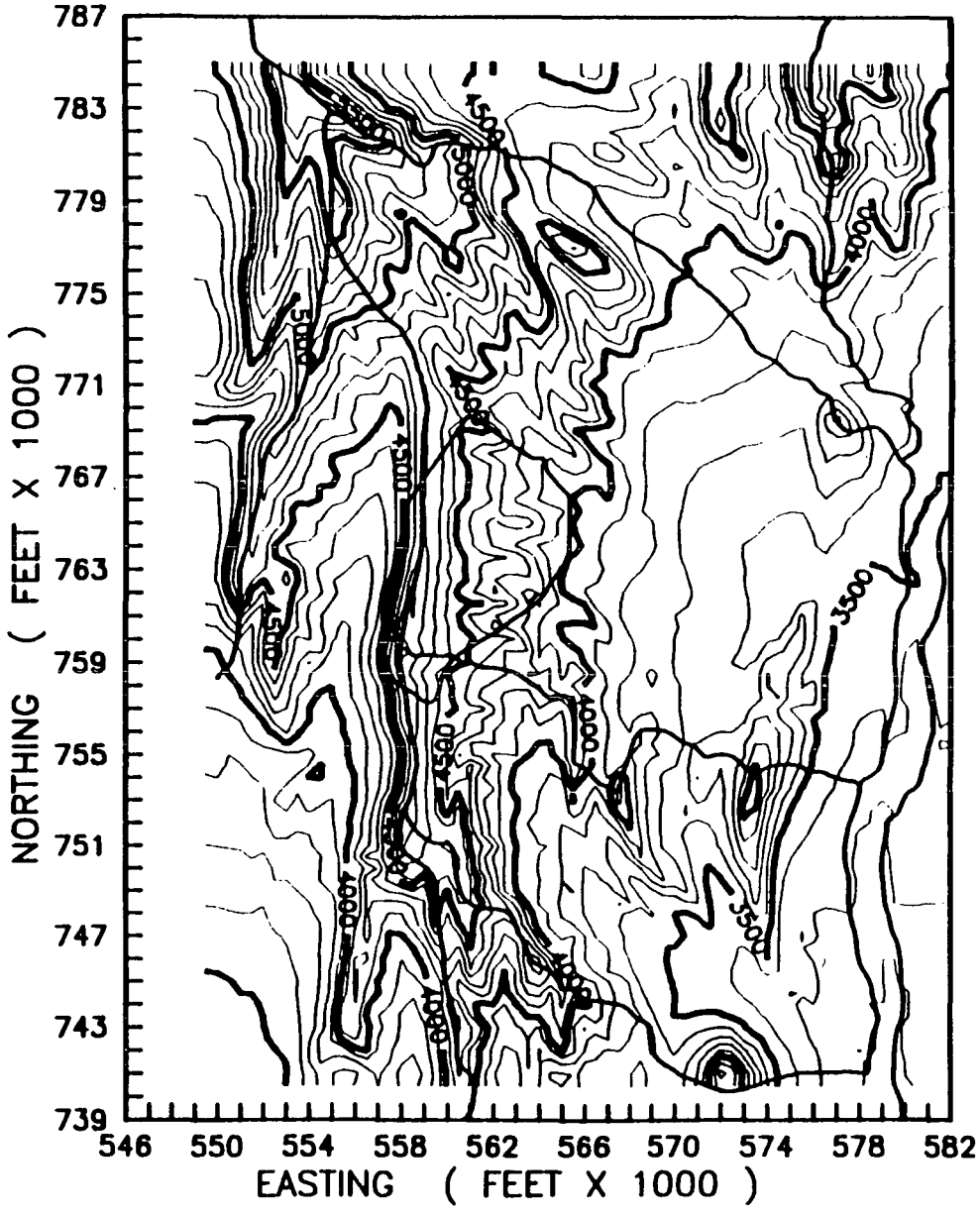
COKRIGED VARIANCES (MM*MM) MODEL Z5



KRIGED AVERAGE ANNUAL PRECIPITATION (MM)



WATERSHED BOUNDARIES



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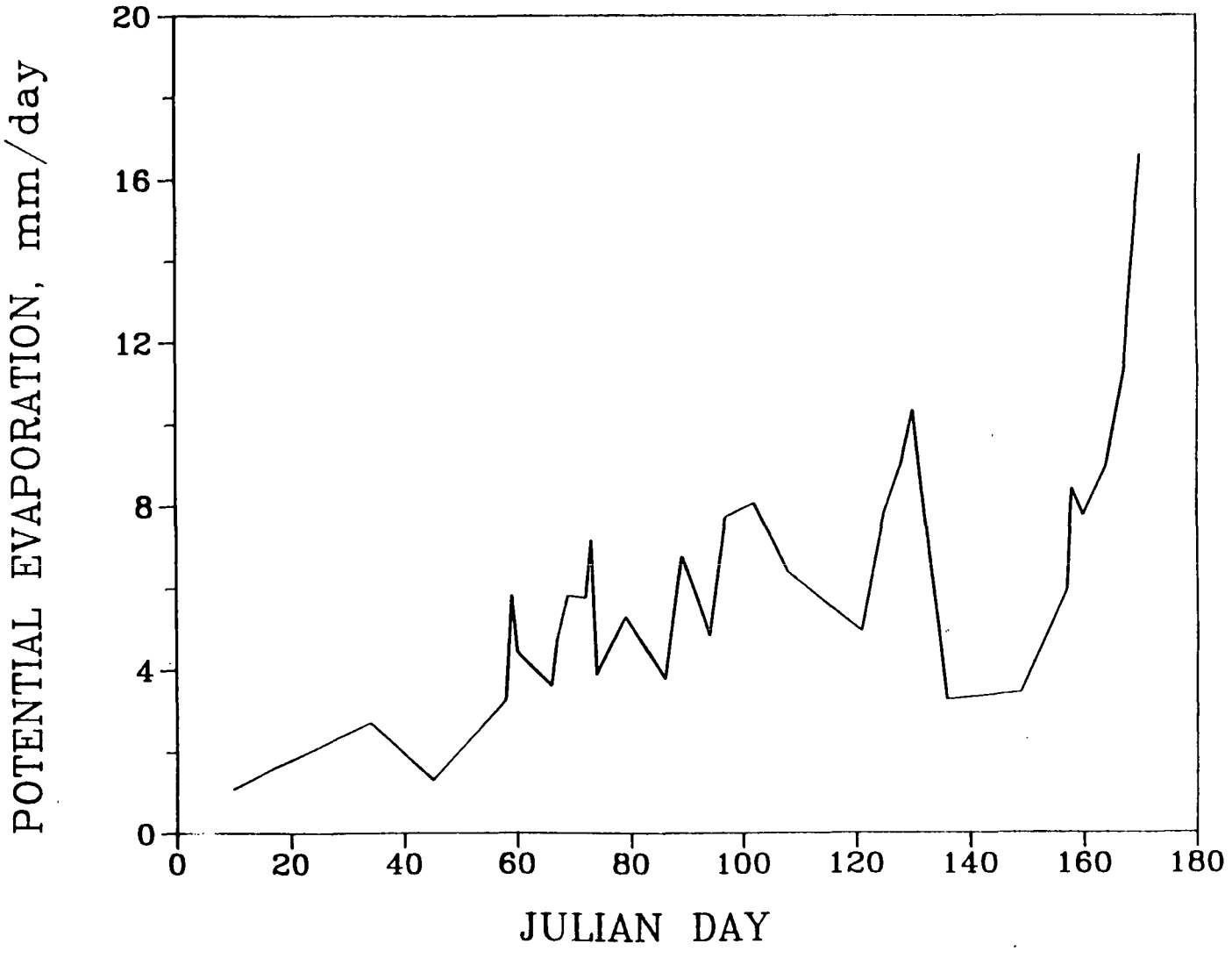
PHOTOGRAPH:
BOWEN RATIO EVAPORATION STATION

PHOTOGRAPH:
EDDY CORRELATION STATION

PHOTOGRAPH:
EVAPORATION PAN

ESTIMATES USING CLASS A EVAP PAN



ENERGY BALANCE

NET RADIATION - GROUND HEAT -

LATENT HEAT - SENSIBLE HEAT = 0

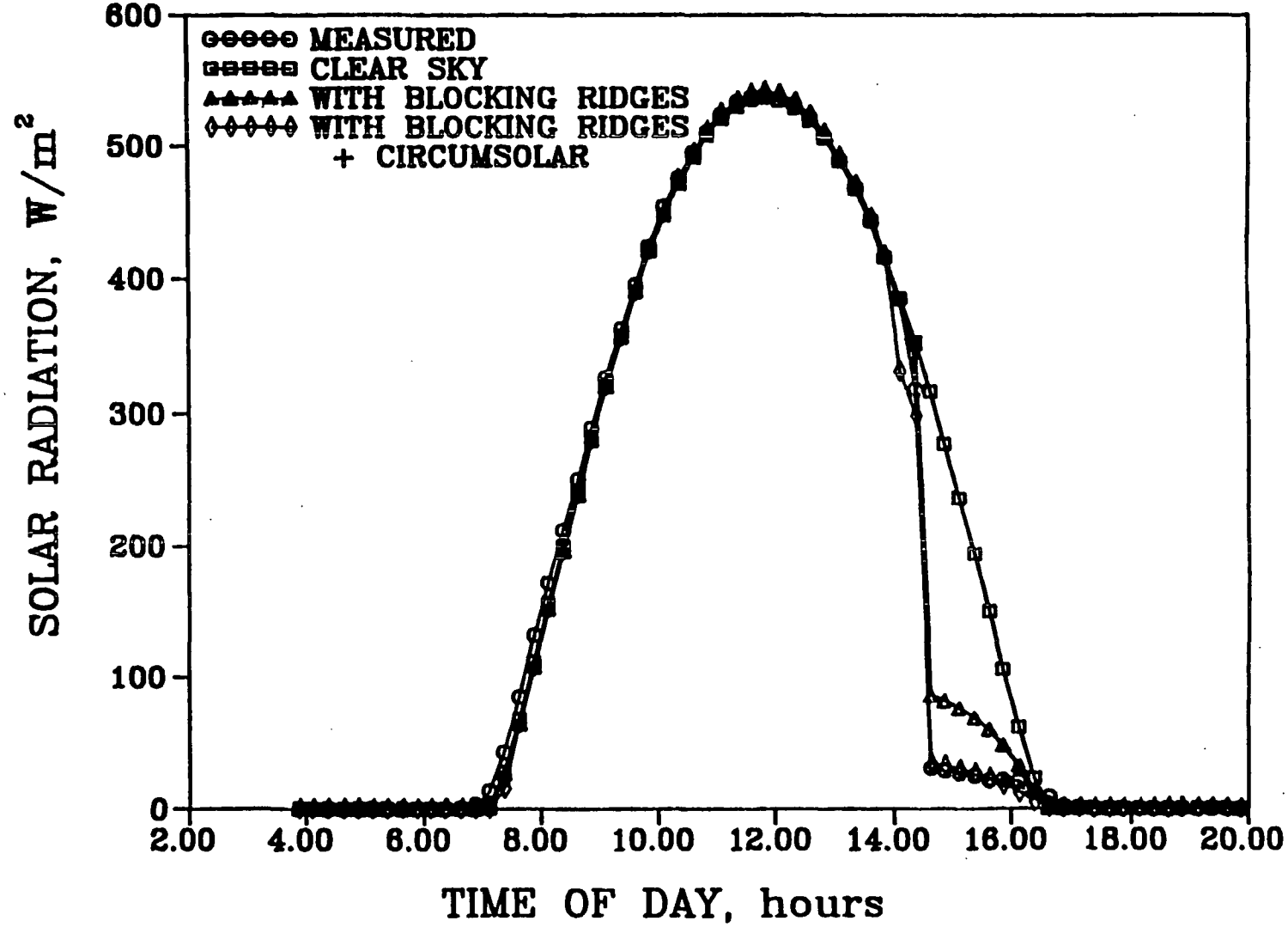
RADIATION BALANCE

INCOMING SHORTWAVE + INCOMING LONGWAVE -

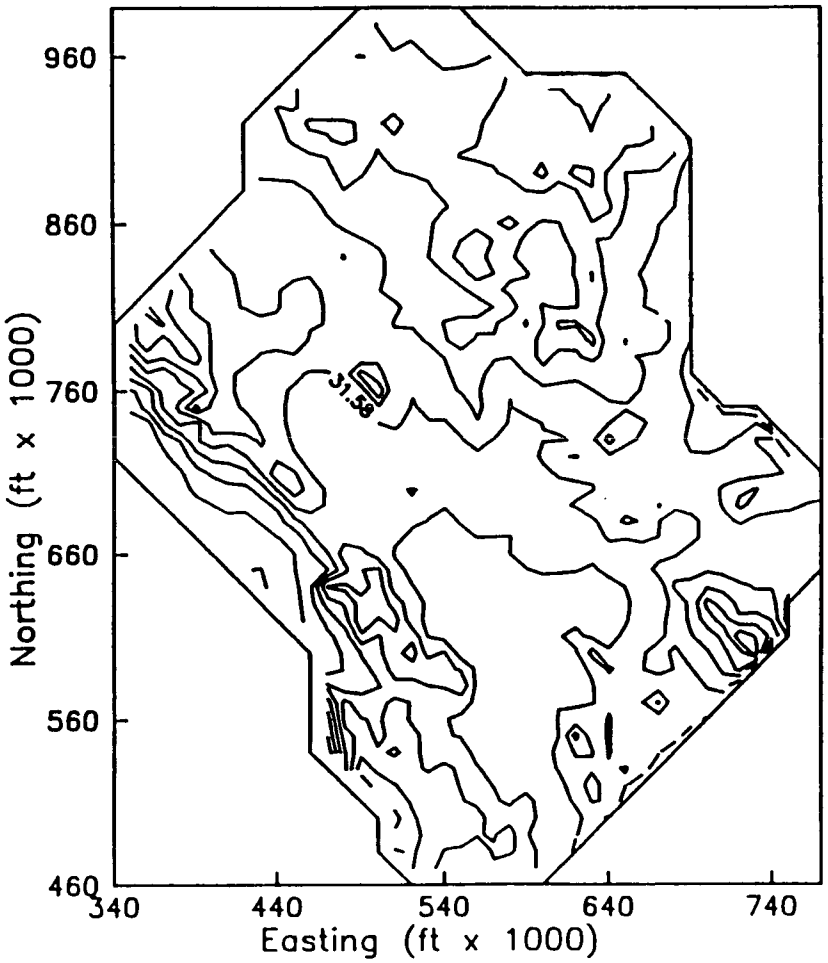
OUGOING SHORTWAVE - OUTGOING LONGWAVE = 0

PHOTOGRAPH:
WEATHER STATION AT JACKASS FLATS

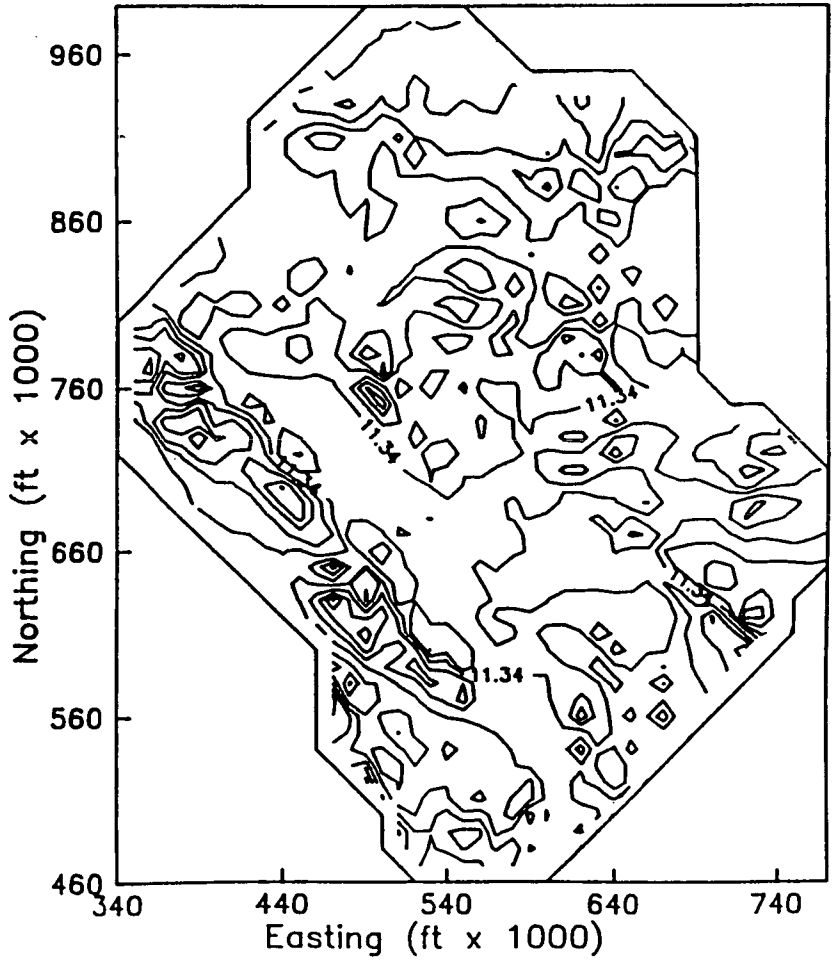
THREE STAGES OF MODEL CALIBRATION



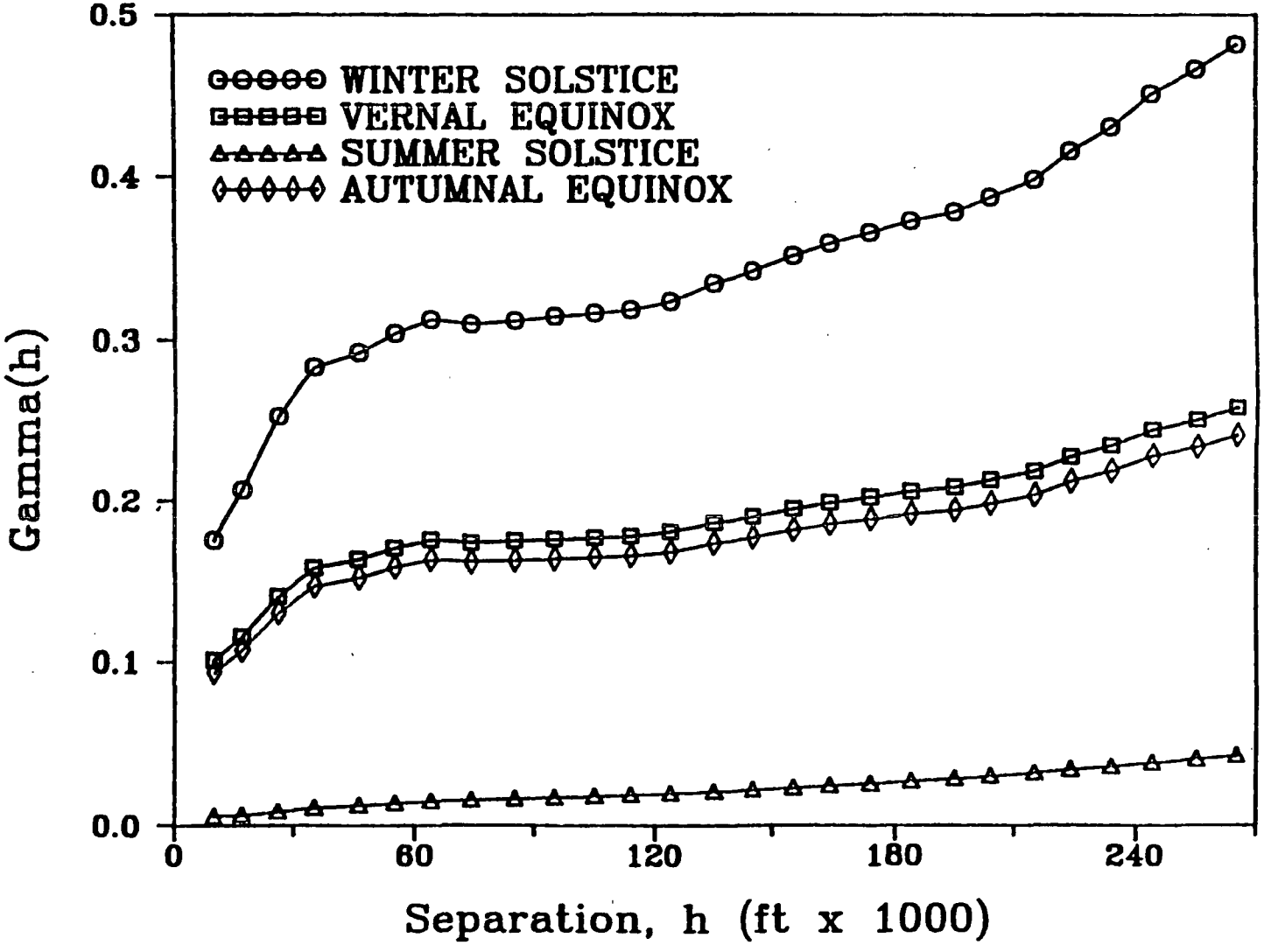
Summer Solstice (With Slope and Aspect)



Winter Solstice (With Slope and Aspect)



TOTAL SOLAR RADIATION WITH SLOPE AND ASPECT



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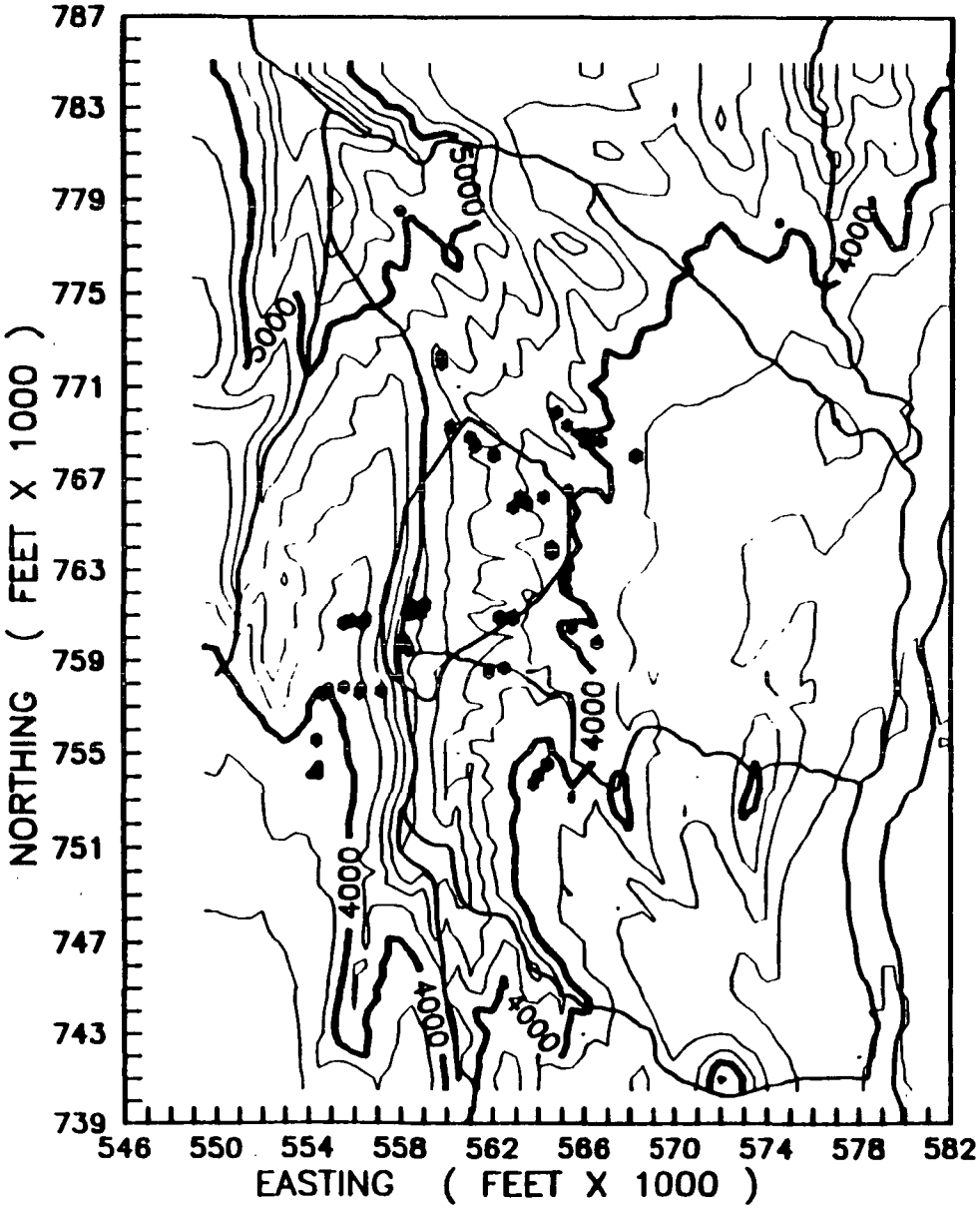
NEUTRON HOLE LOCATIONS



GENERALIZED TOPOGRAPHIC SETTINGS
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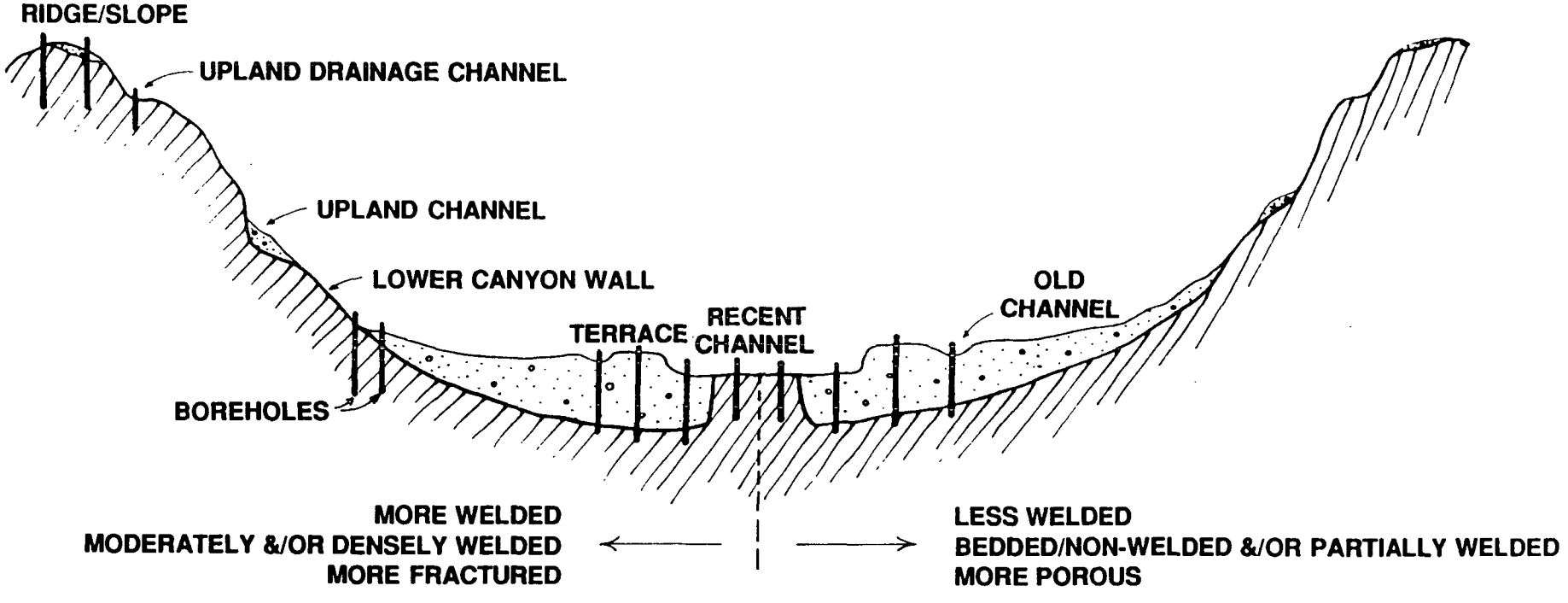
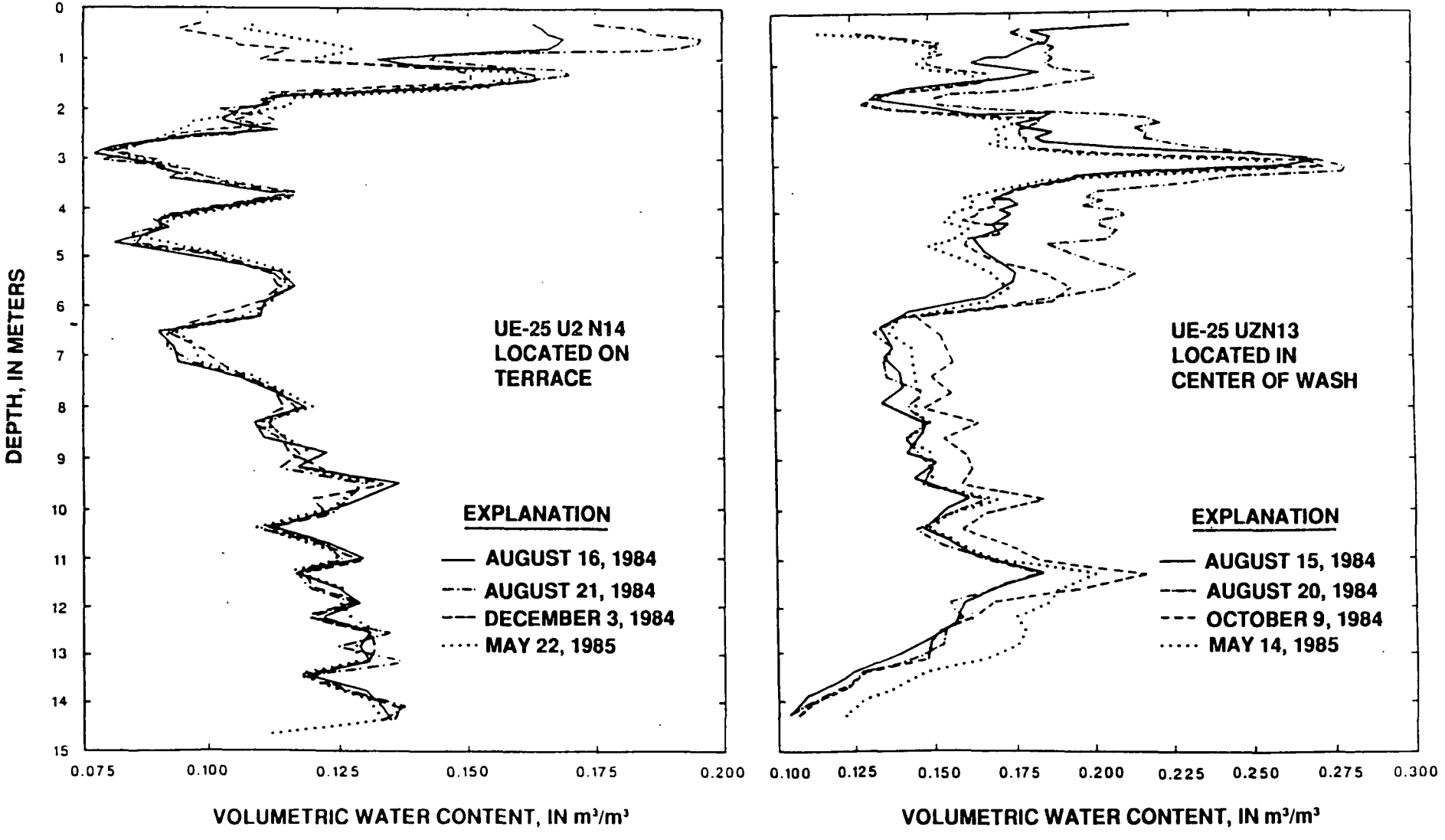
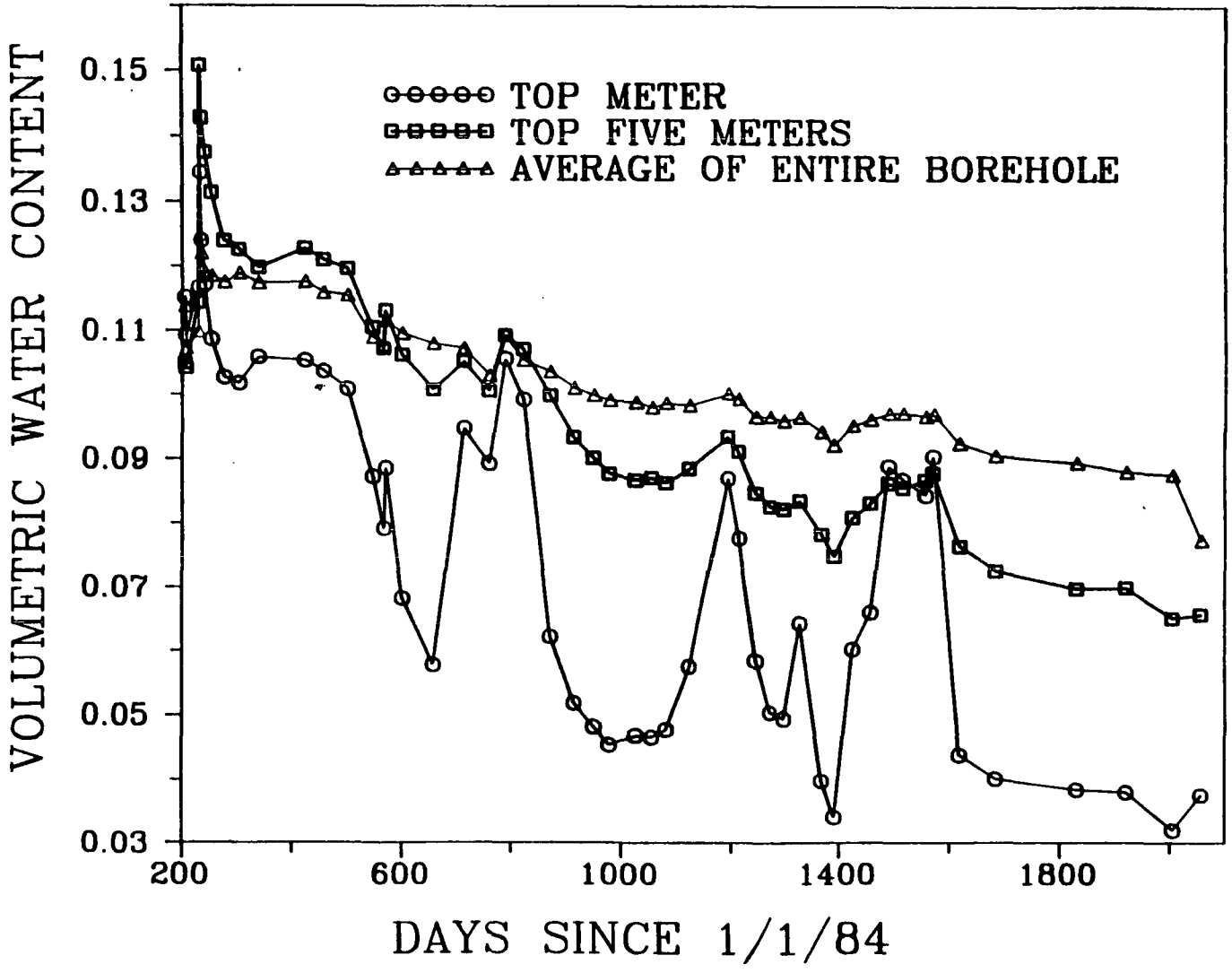


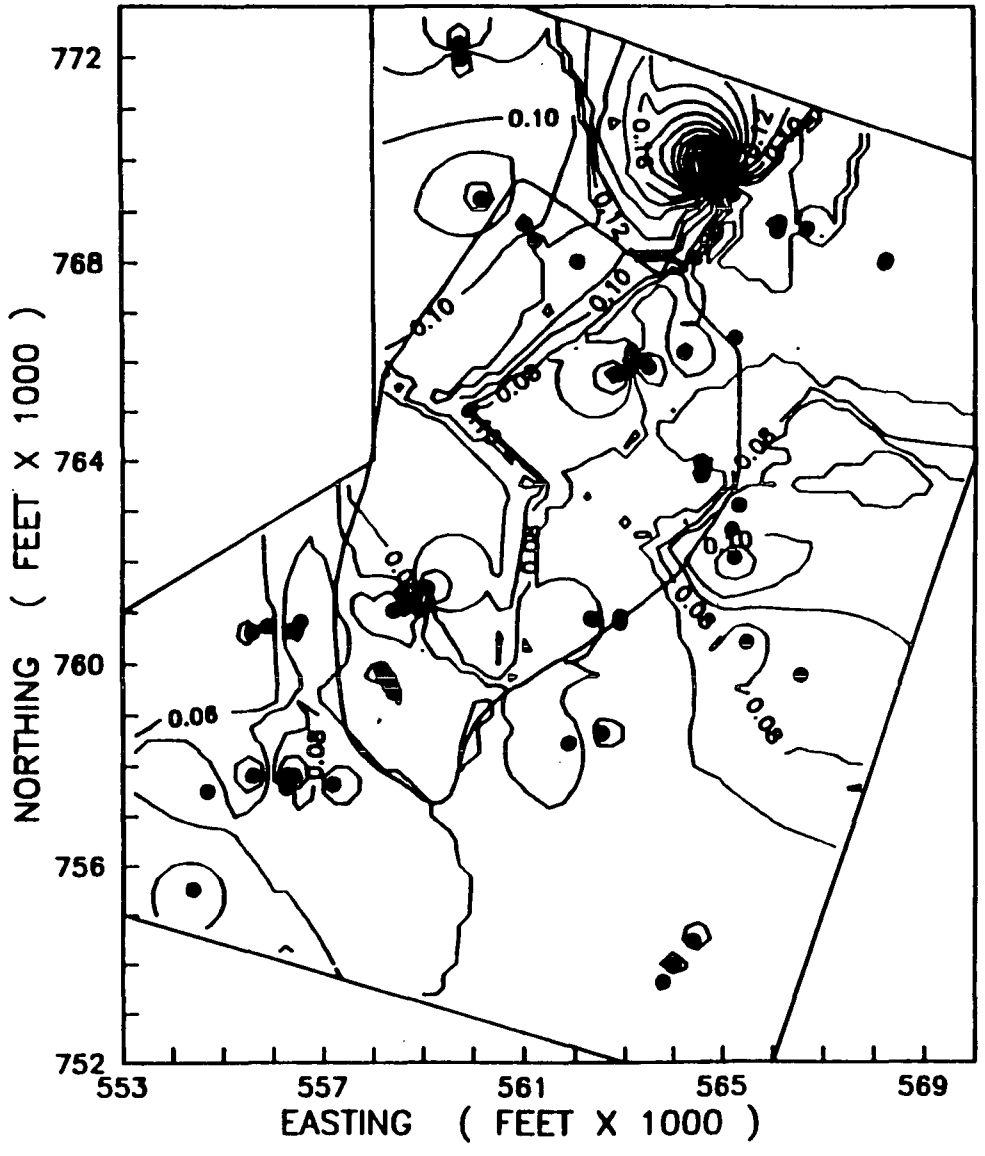
WATER CONTENT PROFILES FOR N14 AND N13 BEFORE AND AFTER RAINFALL EVENT AUGUST 19, 1984, IN PAGANY WASH



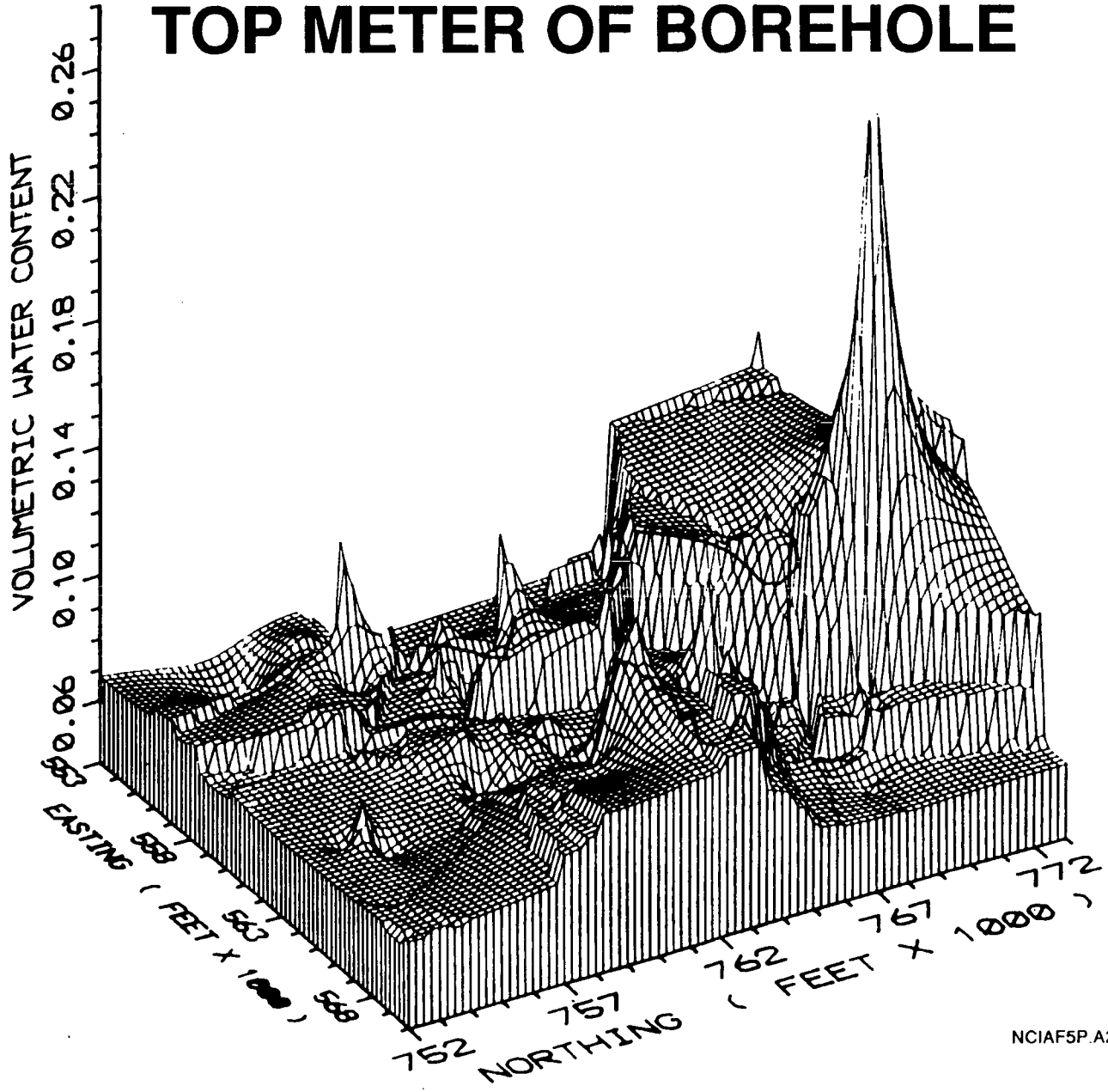
USW-N7 PAGANY WASH



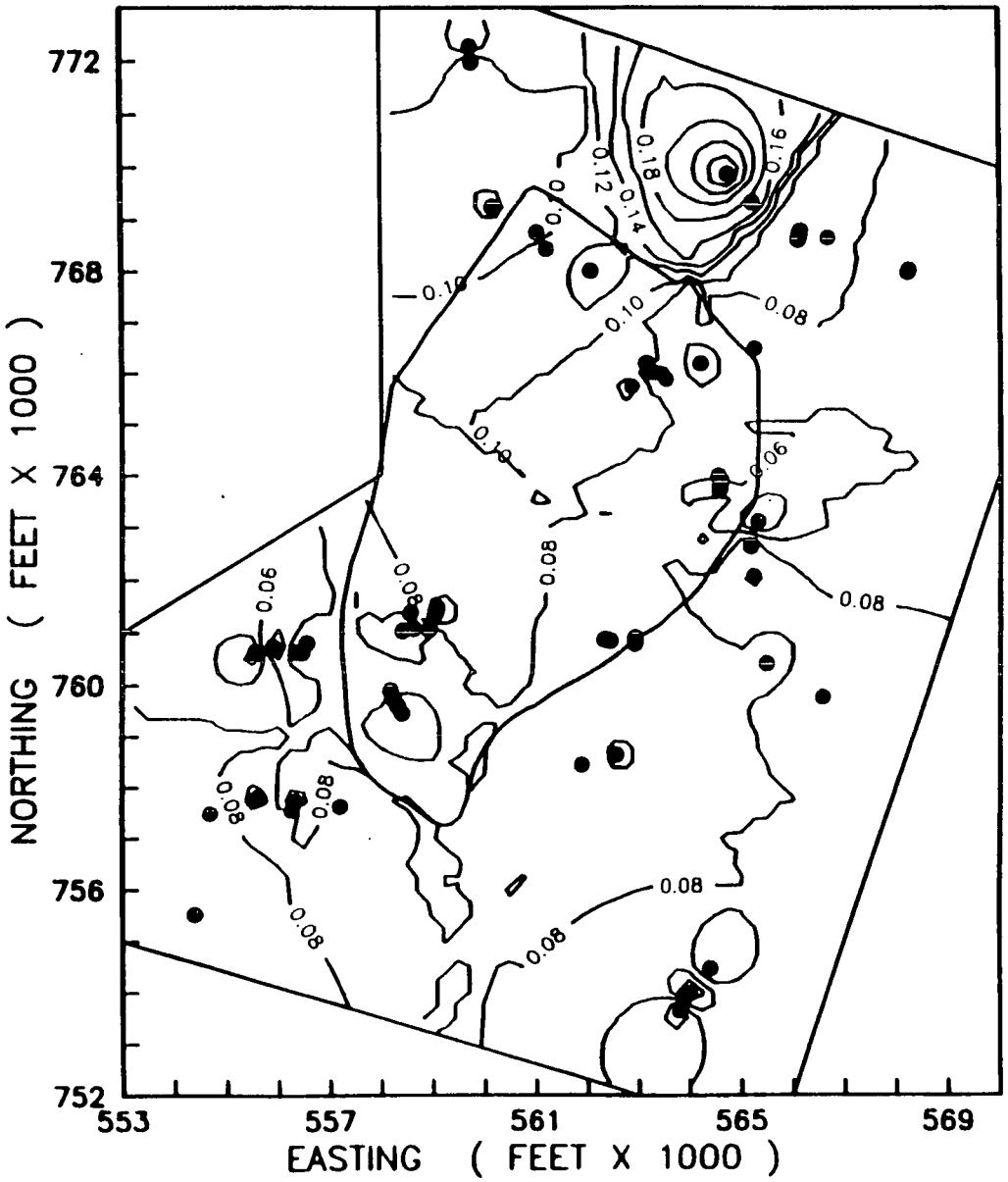
WATER CONTENT
TOP METER OF BOREHOLE



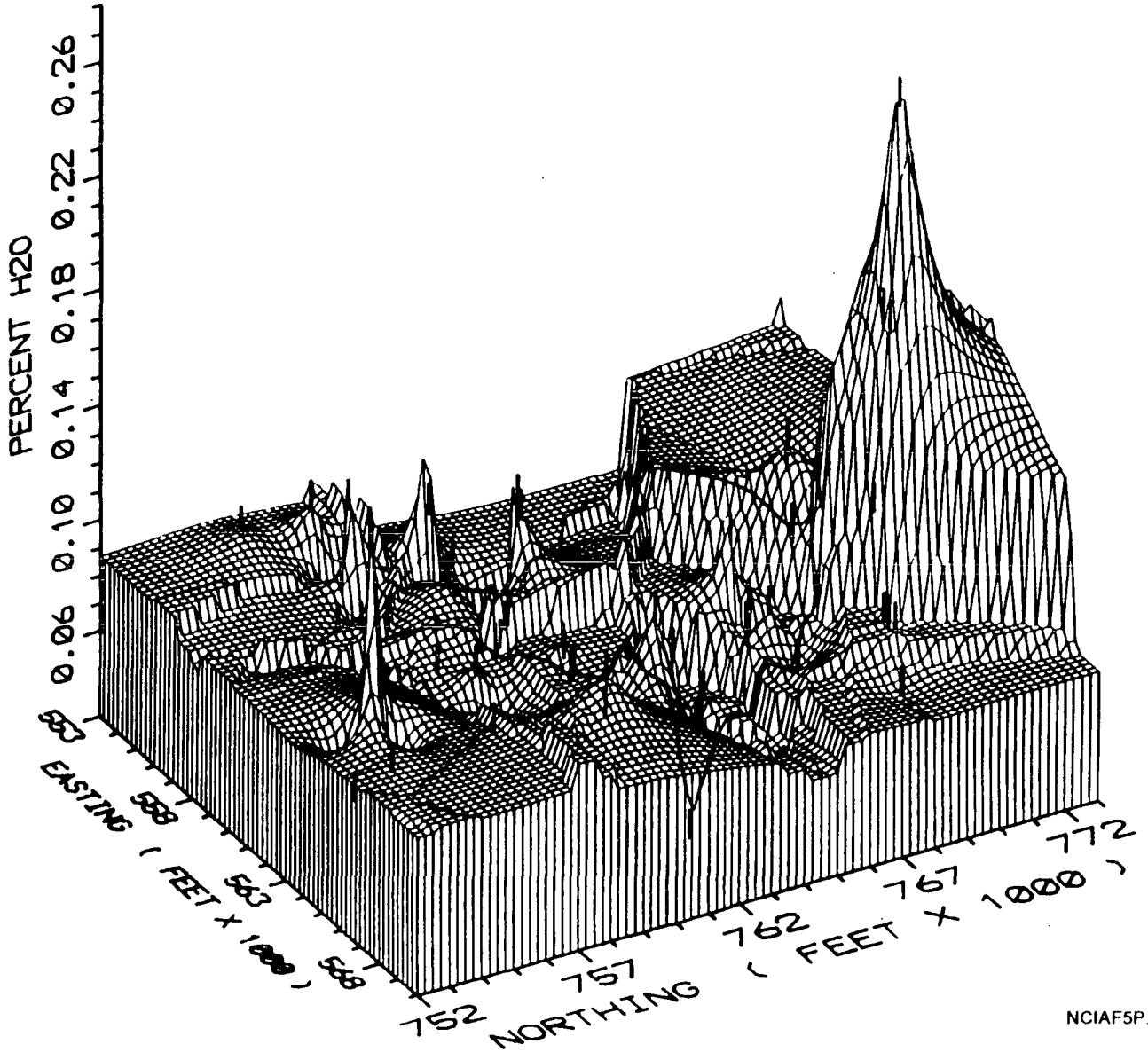
AVERAGE WATER CONTENT
TOP METER OF BOREHOLE



AVERAGE WATER CONTENT IN FIRST METER OF BEDROCK



AVERAGE WATER CONTENT TOP METER OF BEDROCK



VOLUMETRIC WATER CONTENT FROM NEUTRON LOGGING TOP METER OF BEDROCK

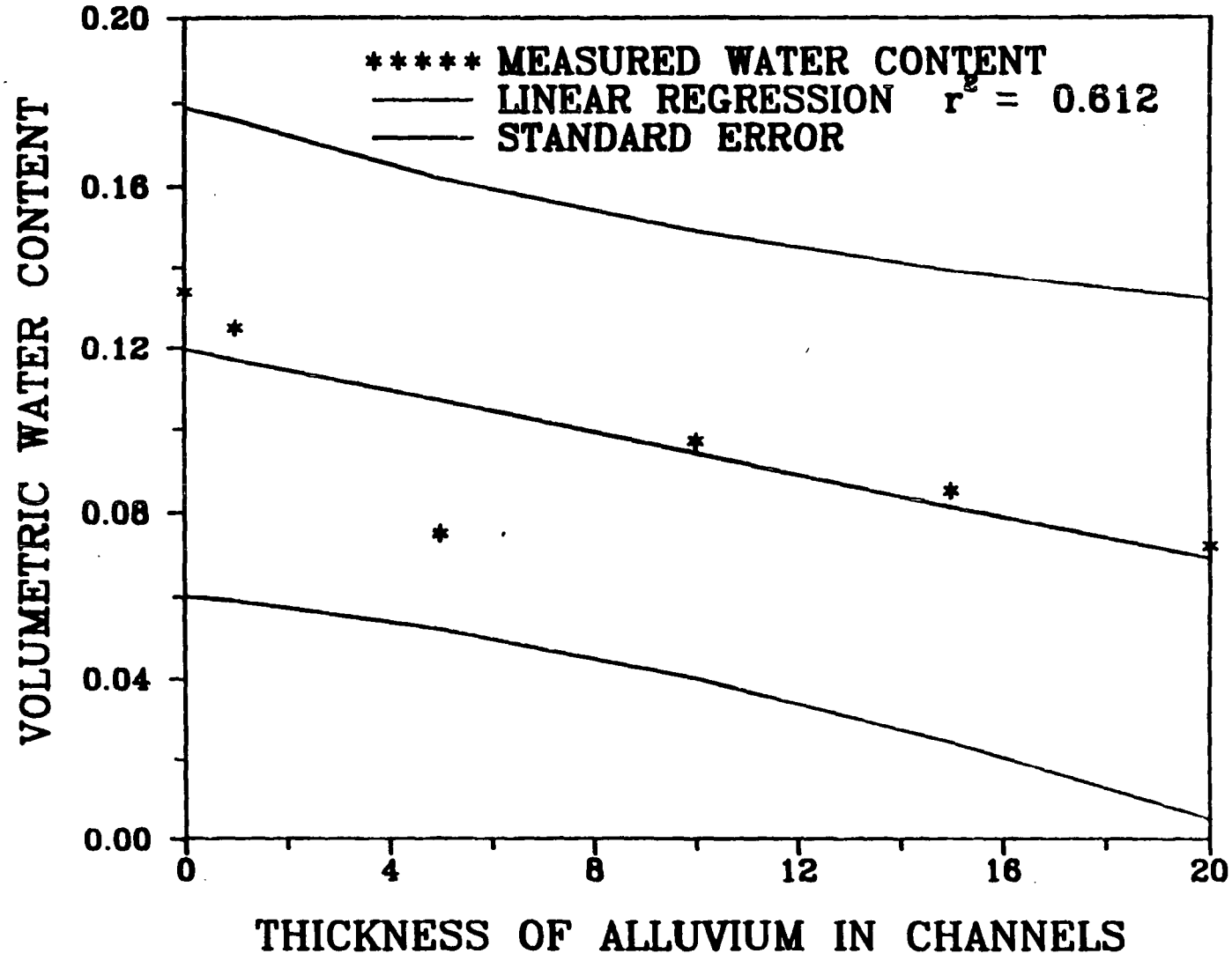
	UNDER ALLUVIUM	EXPOSED AT SURFACE	ALL SURFACES
CANYON WASH			
AVERAGE	0.079	0.134	0.088
MAXIMUM	0.096	0.177	0.108
MINIMUM	0.061	0.084	0.067
SIDESLOPES AND RIDGES			
AVERAGE	0.089	0.075	0.079
MAXIMUM	0.111	0.112	0.112
MINIMUM	0.071	0.046	0.053

VOLUMETRIC WATER CONTENT FROM NEUTRON LOGGING TOP METER OF BEDROCK

IN ACTIVE CHANNEL BOTTOM

	UNDER ALLUVIUM	EXPOSED AT SURFACE
LESS WELDED		
AVERAGE	0.088	0.203
MAXIMUM	0.103	0.253
MINIMUM	0.054	0.136
MORE WELDED		
AVERAGE	0.090	0.100
MAXIMUM	0.108	0.140
MINIMUM	0.077	0.059

WATER CONTENT OF TOP METER OF BEDROCK FROM NEUTRON HOLES IN CHANNELS



CHARACTERIZATION OF UNSATURATED ZONE INFILTRATION

METHODS

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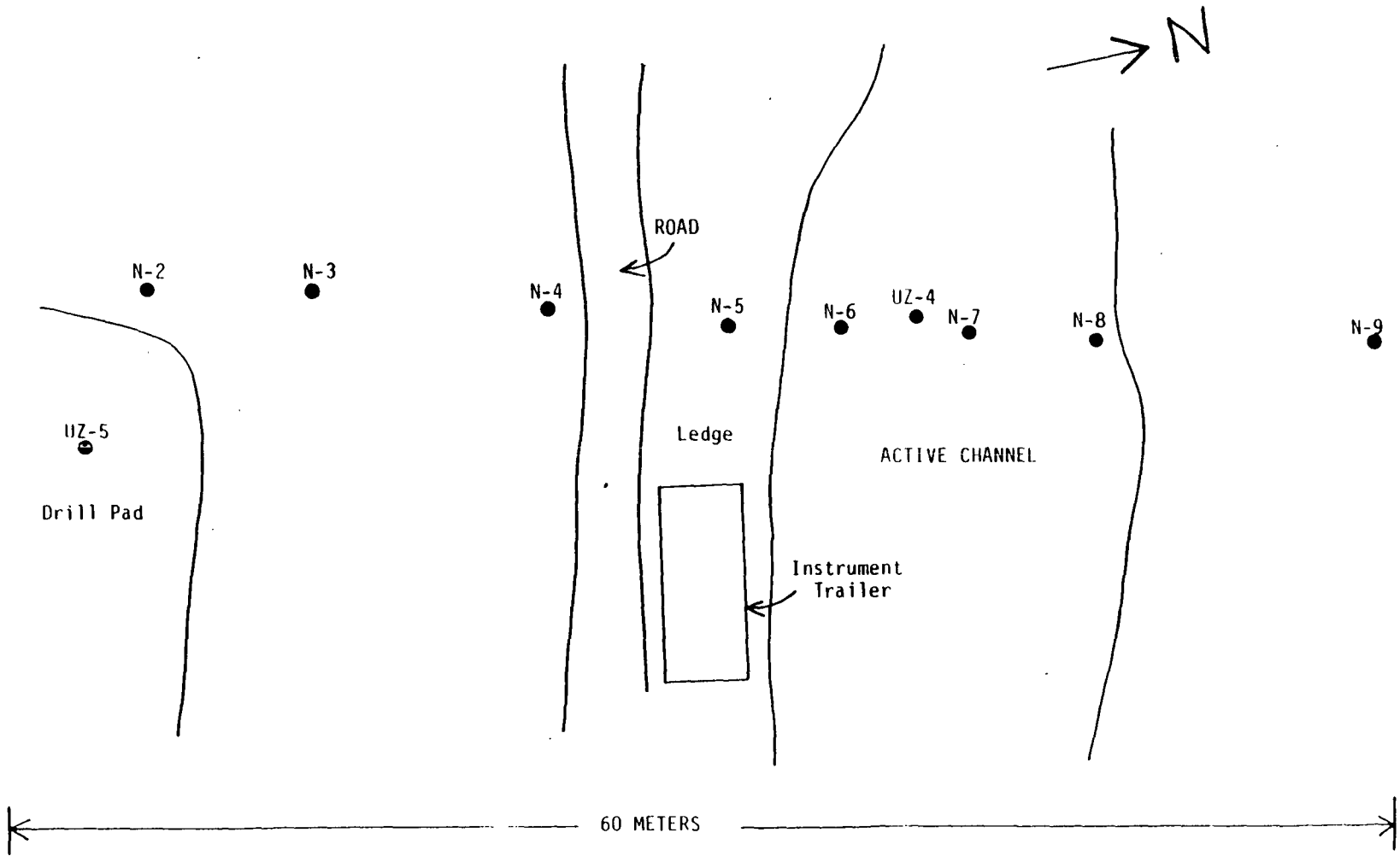
  - PONDING

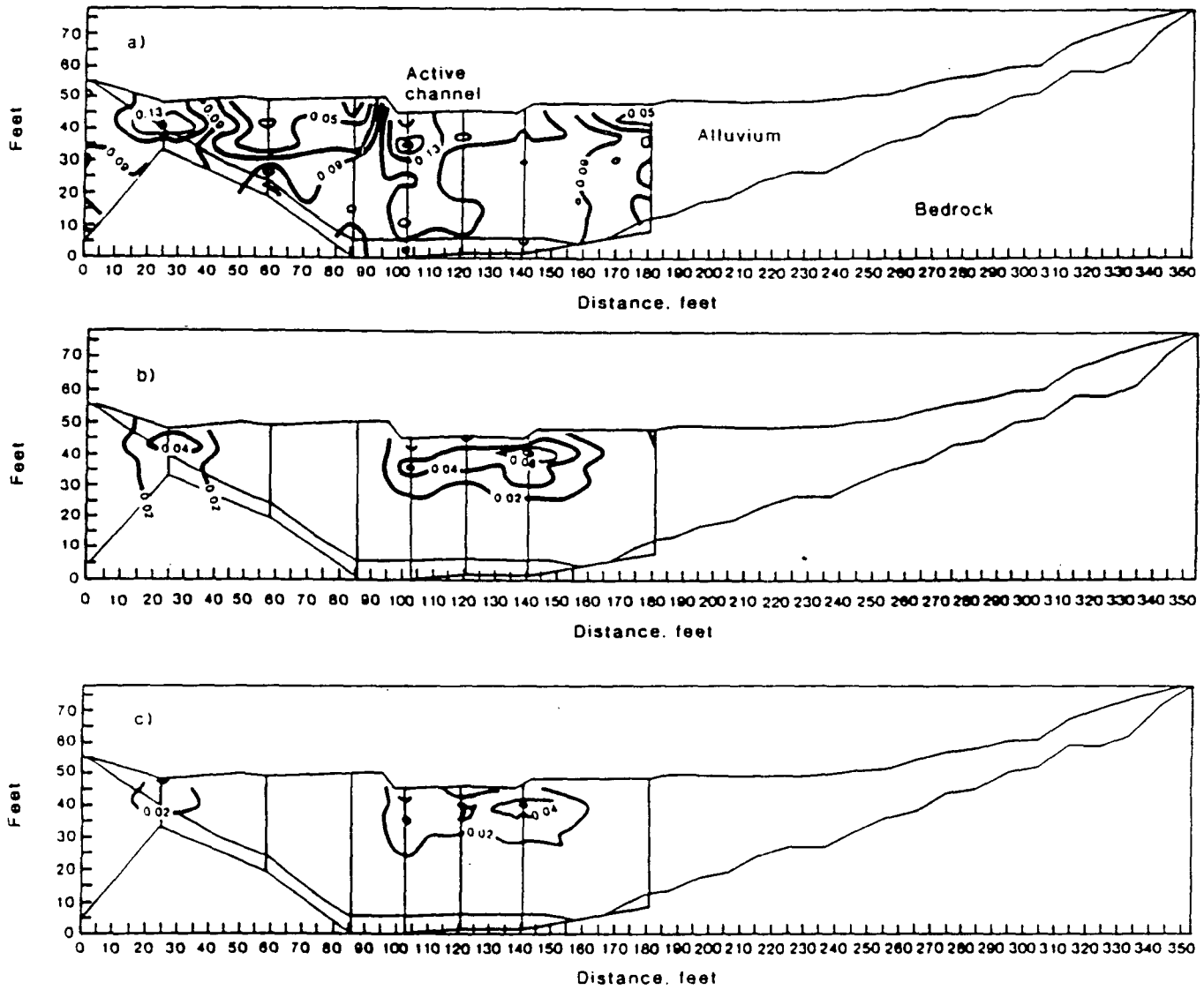
PHOTOGRAPH:
AERIAL VIEW OF PAGANY WASH

PHOTOGRAPH:
PAGANY CROSS-SECTION
LOOKING WEST OF WASH

PAGANY WASH
AERIAL VIEW OF BOREHOLE LOCATIONS



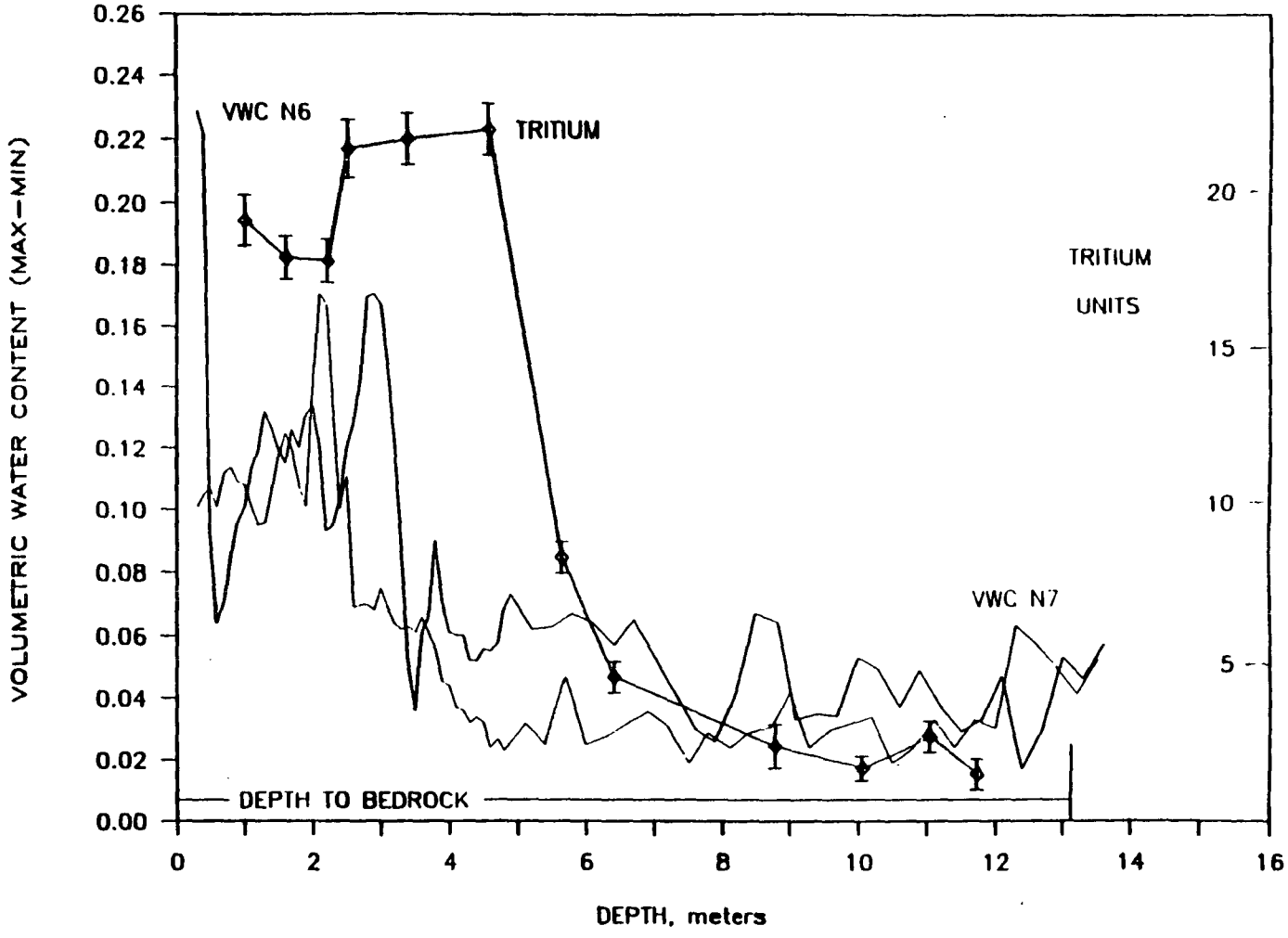
PAGANY WASH CROSS-SECTIONS (ESTIMATED RAINFALL IN RANGE OF 1 TO 2 INCHES)



VOLUMETRIC WATER CONTENT DETERMINED USING NEUTRON METER IN 8 HOLES IN PAGANY WASH IN AUGUST, 1984

A) PRE STORM WATER CONTENTS
B) DIFFERENCE BETWEEN PRE STORM AND 24 HOUR POST STORM WATER CONTENT
C) DIFFERENCE BETWEEN PRE STORM AND 48 HOUR POST STORM WATER CONTENT

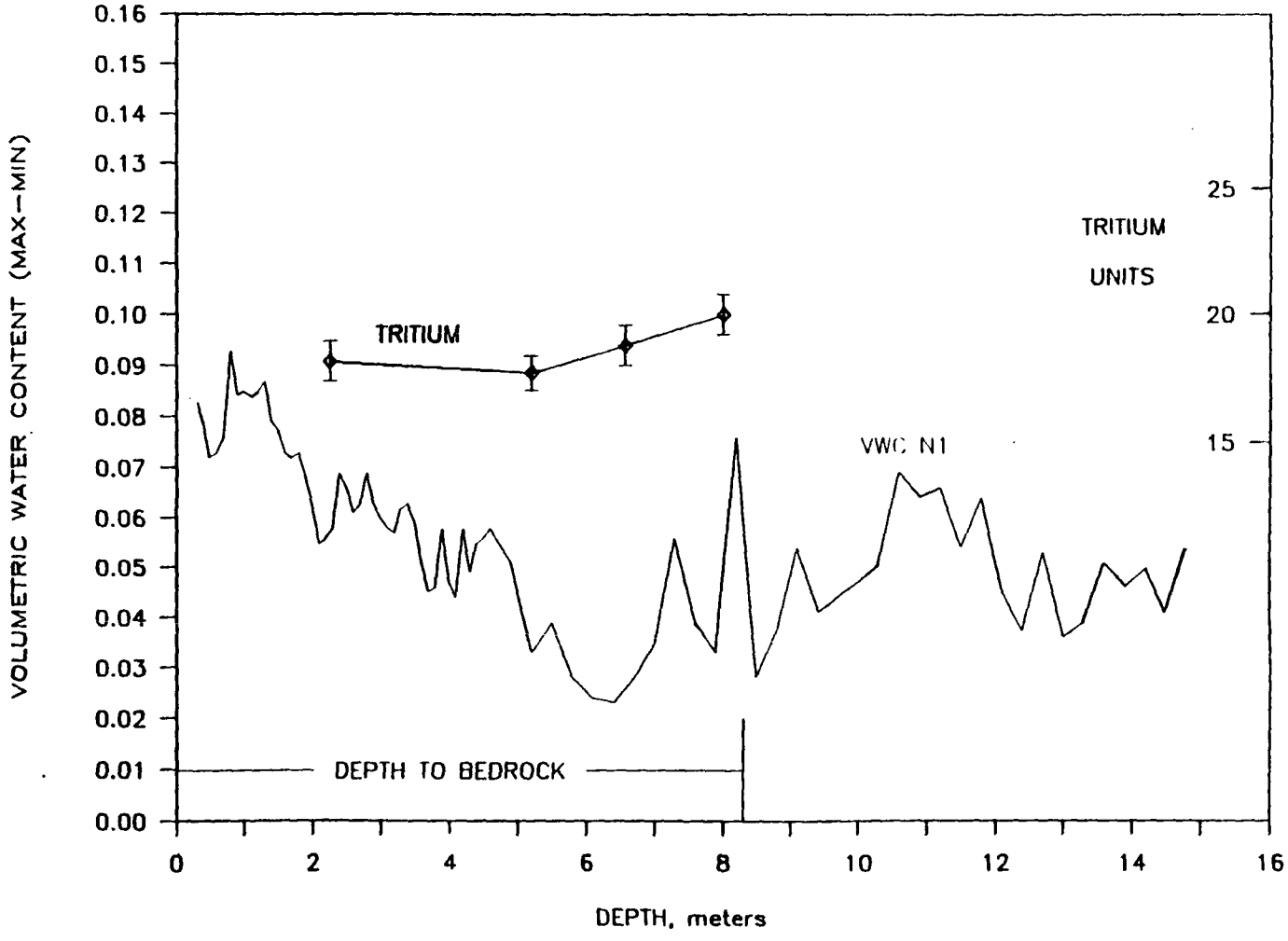
UZ-4



VOLUMETRIC WATER CONTENT INDICATED AS MAXIMUM MINUS MINIMUM VALUES EVER RECORDED SINCE 1984

PHOTOGRAPH:
WASHED OUT SIDESLOPE
WITH EXPOSED CALICHE

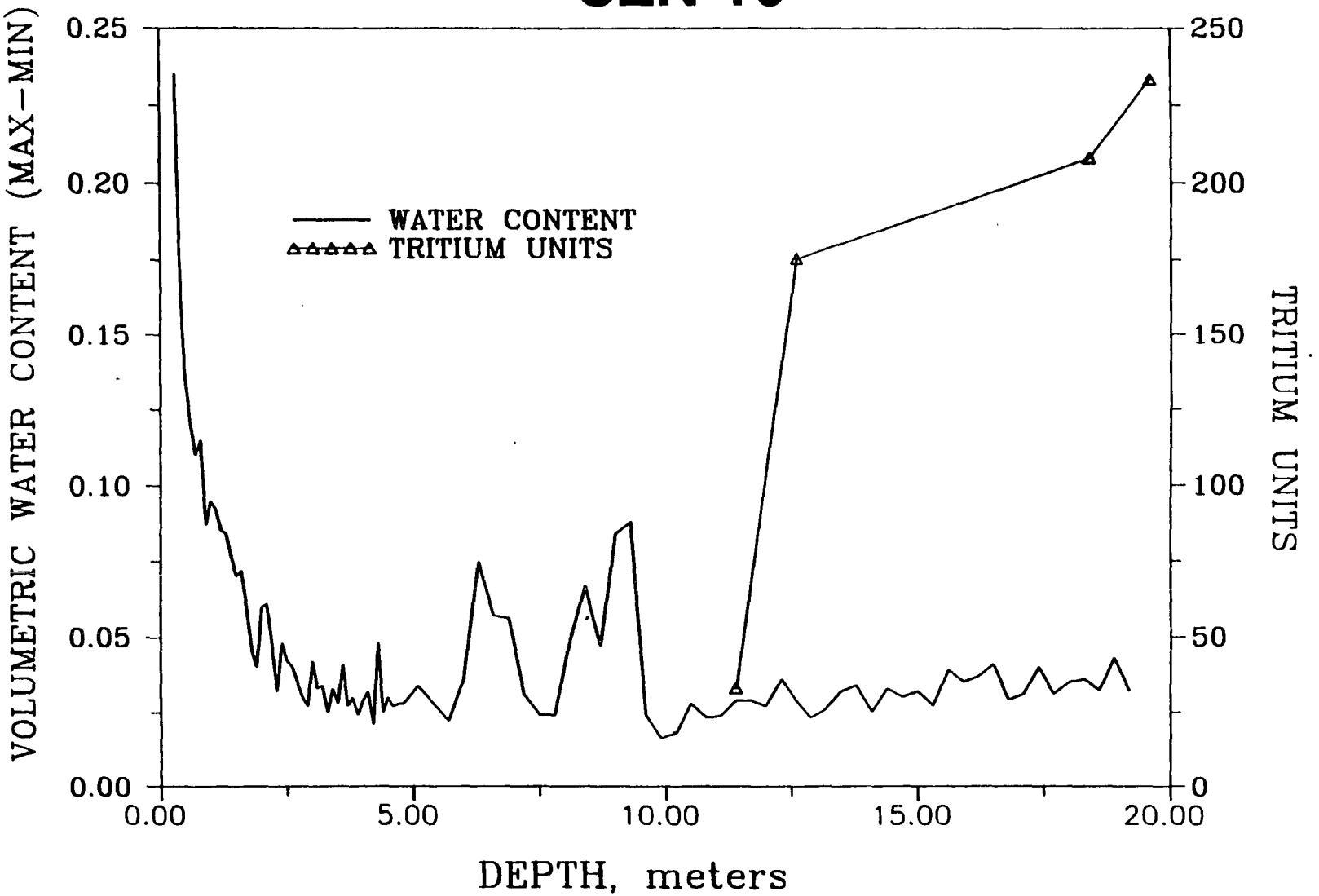
UZN-1



VOLUMETRIC WATER CONTENT INDICATED AS MAXIMUM MINUS MINIMUM VALUES EVER RECORDED SINCE 1984

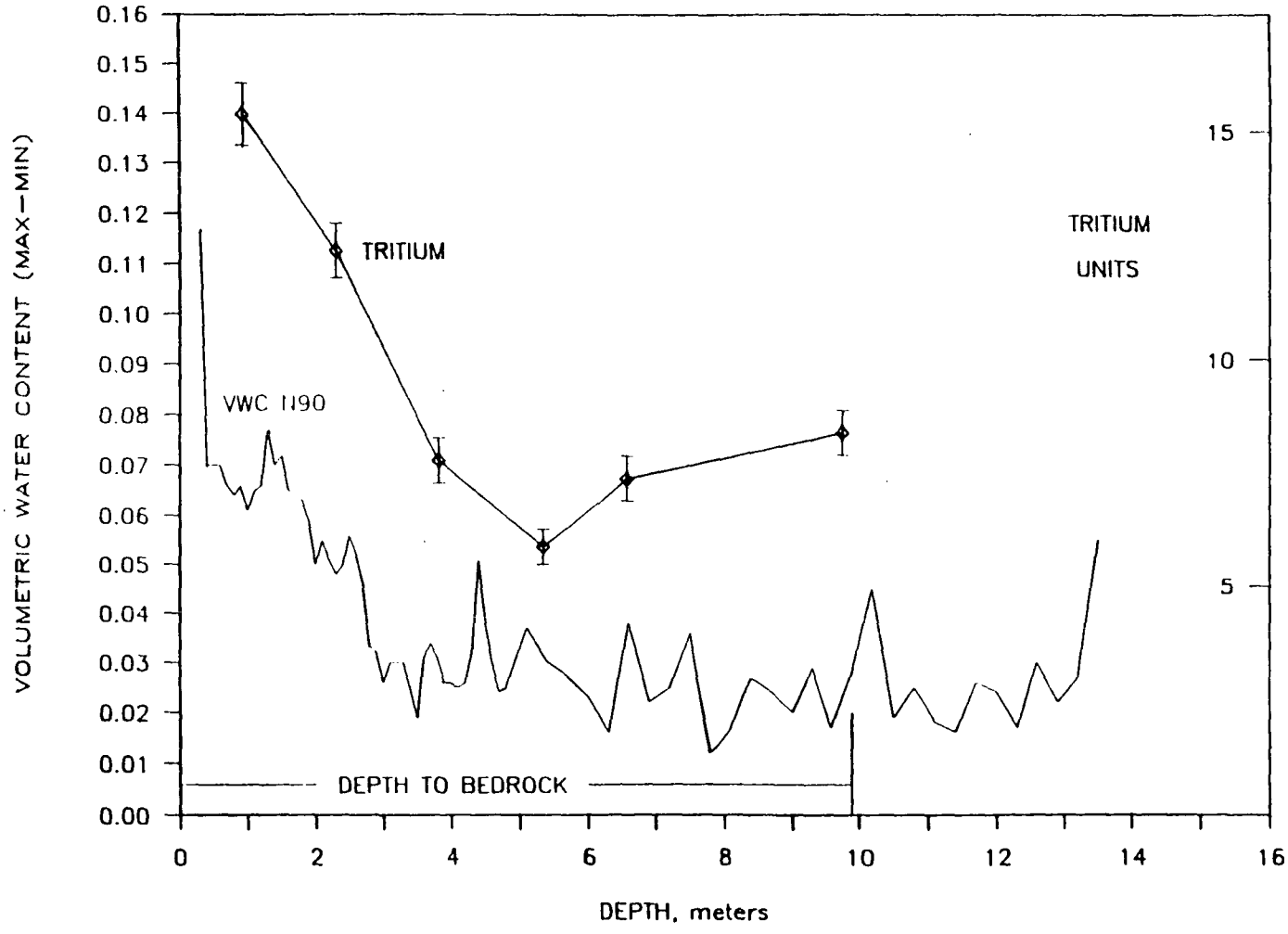
PHOTOGRAPH:
NEUTRON HOLE N-10

UZN-10



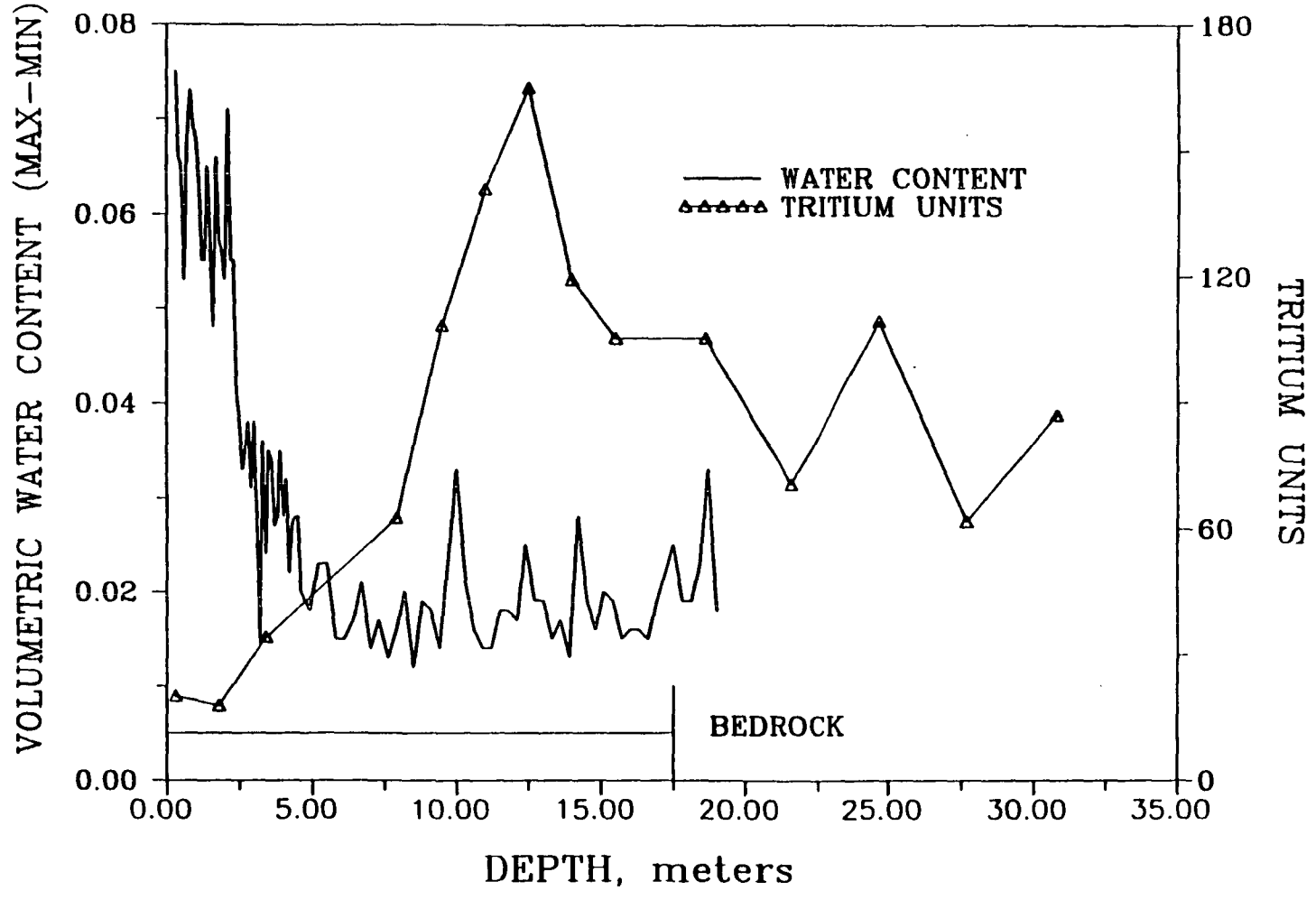
VOLUMETRIC WATER CONTENT INDICATED AS MAXIMUM MINUS MINIMUM VALUES EVER RECORDED SINCE 1984

UZN-90



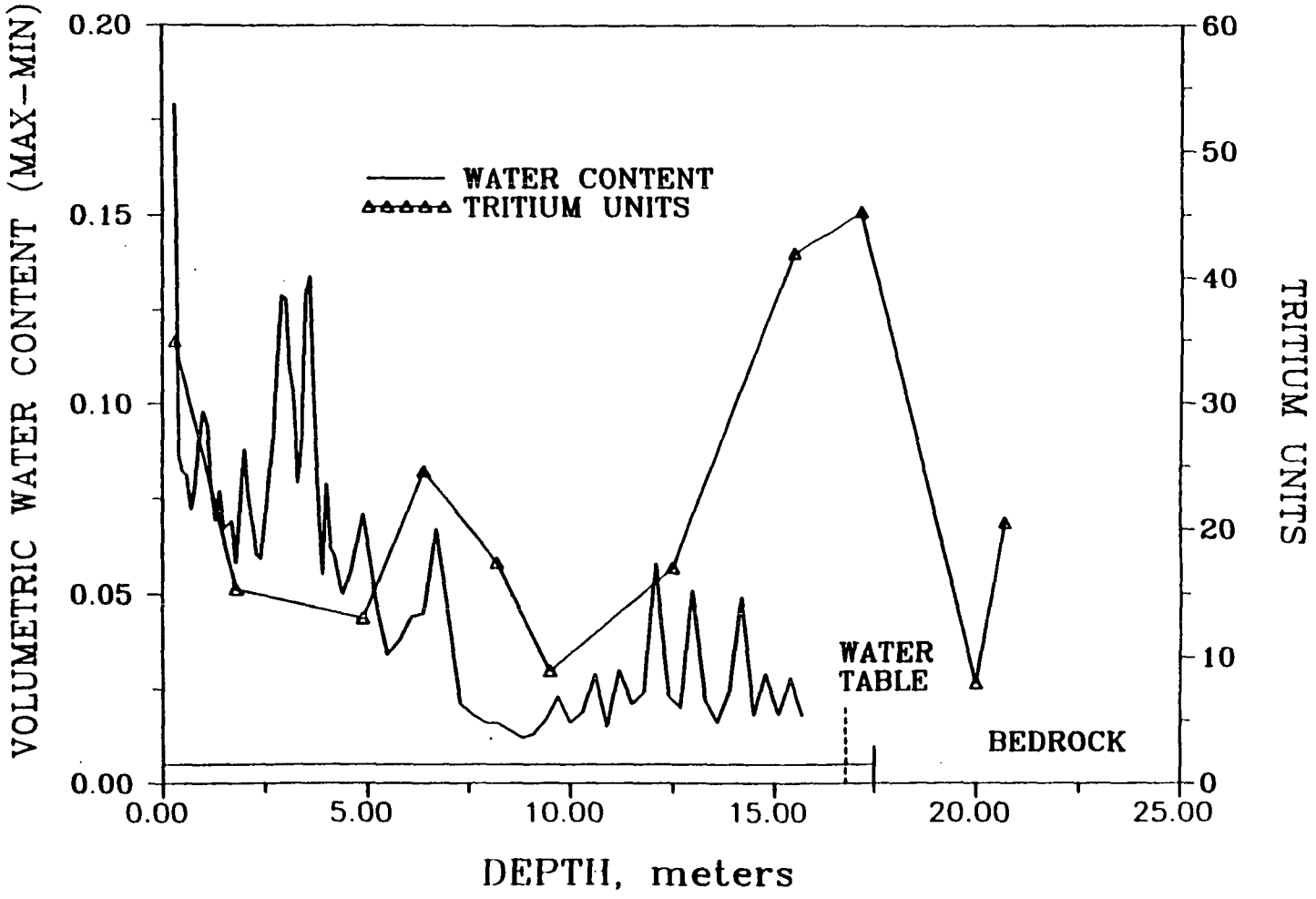
VOLUMETRIC WATER CONTENT INDICATED AS MAXIMUM MINUS MINIMUM VALUES EVER RECORDED SINCE 1984

UZN-92



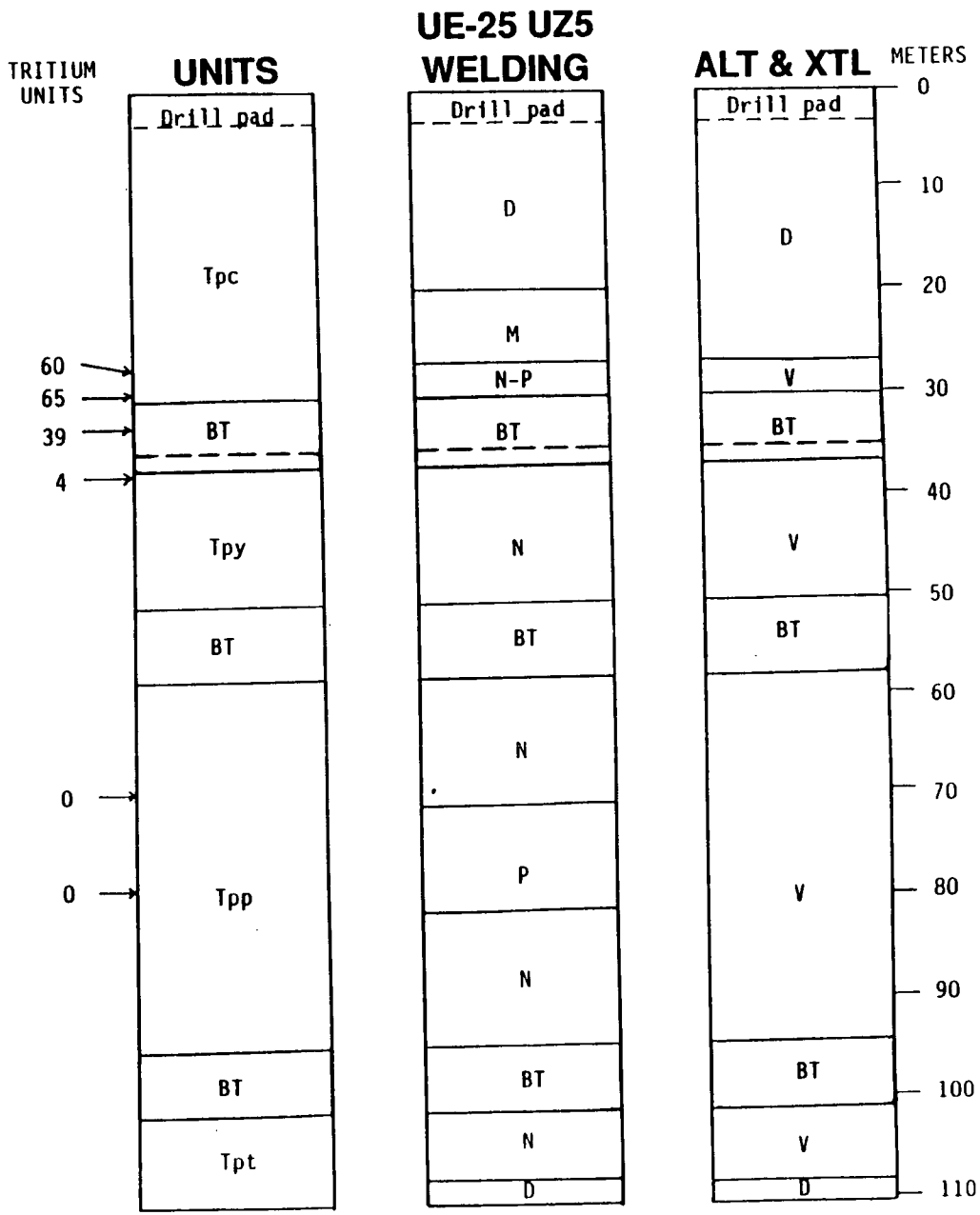
VOLUMETRIC WATER CONTENT INDICATED AS MAXIMUM MINUS MINIMUM VALUES EVER RECORDED SINCE 1984

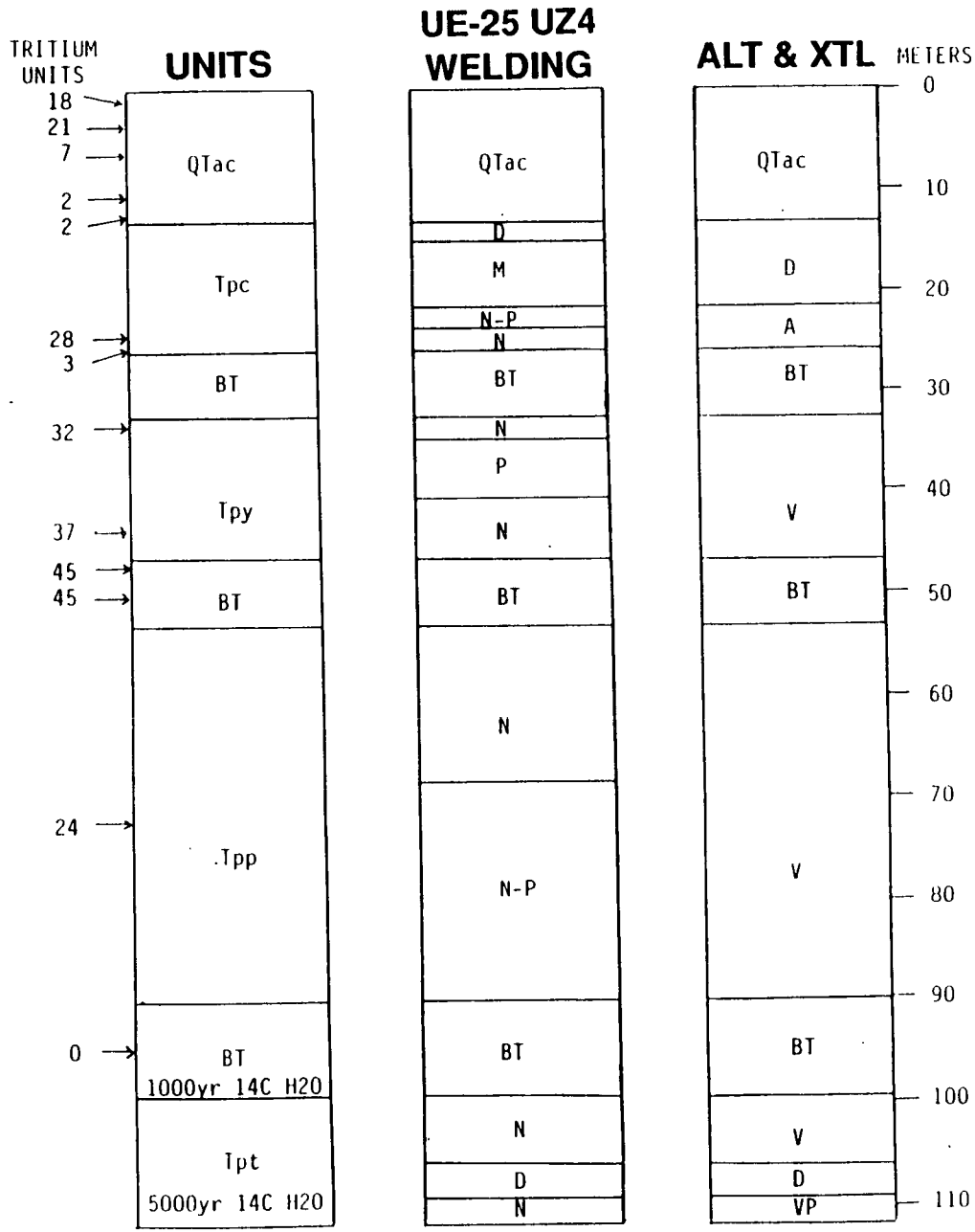
UZN-91



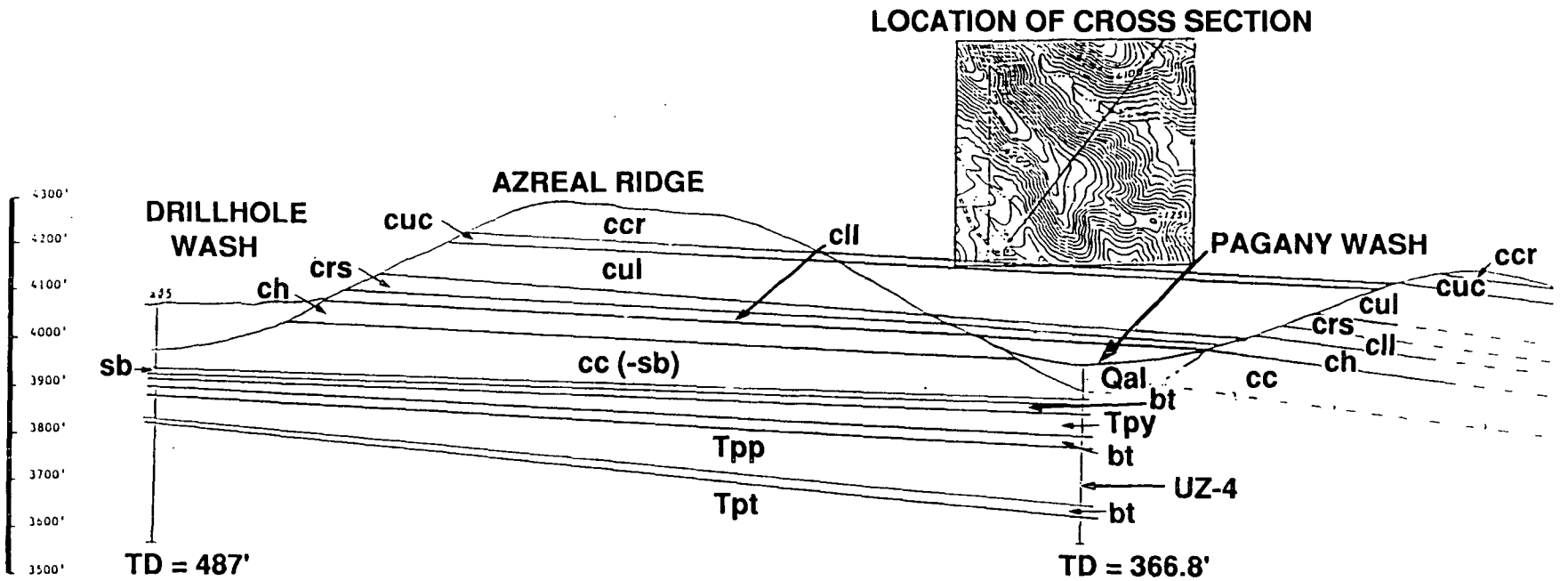
VOLUMETRIC WATER CONTENT INDICATED AS MAXIMUM MINUS MINIMUM VALUES EVER RECORDED SINCE 1984

PHOTOGRAPH:
NEUTRON HOLE N-2


TRITIUM UNITS
UNITS
Drill pad
Tpc
60
65
39
BT
4
Tpy
BT
0
0
Tpp
BT
Tpt
UE-25 UZ5 WELDING
Drill pad
D
M
N-P
BT
N
BT
N
P
N
BT
N
D
ALT & XTL
METERS
Drill pad
D
V
BT
V
BT
V
BT
V
D
0
10
20
30
40
50
60
70
80
90
100
110

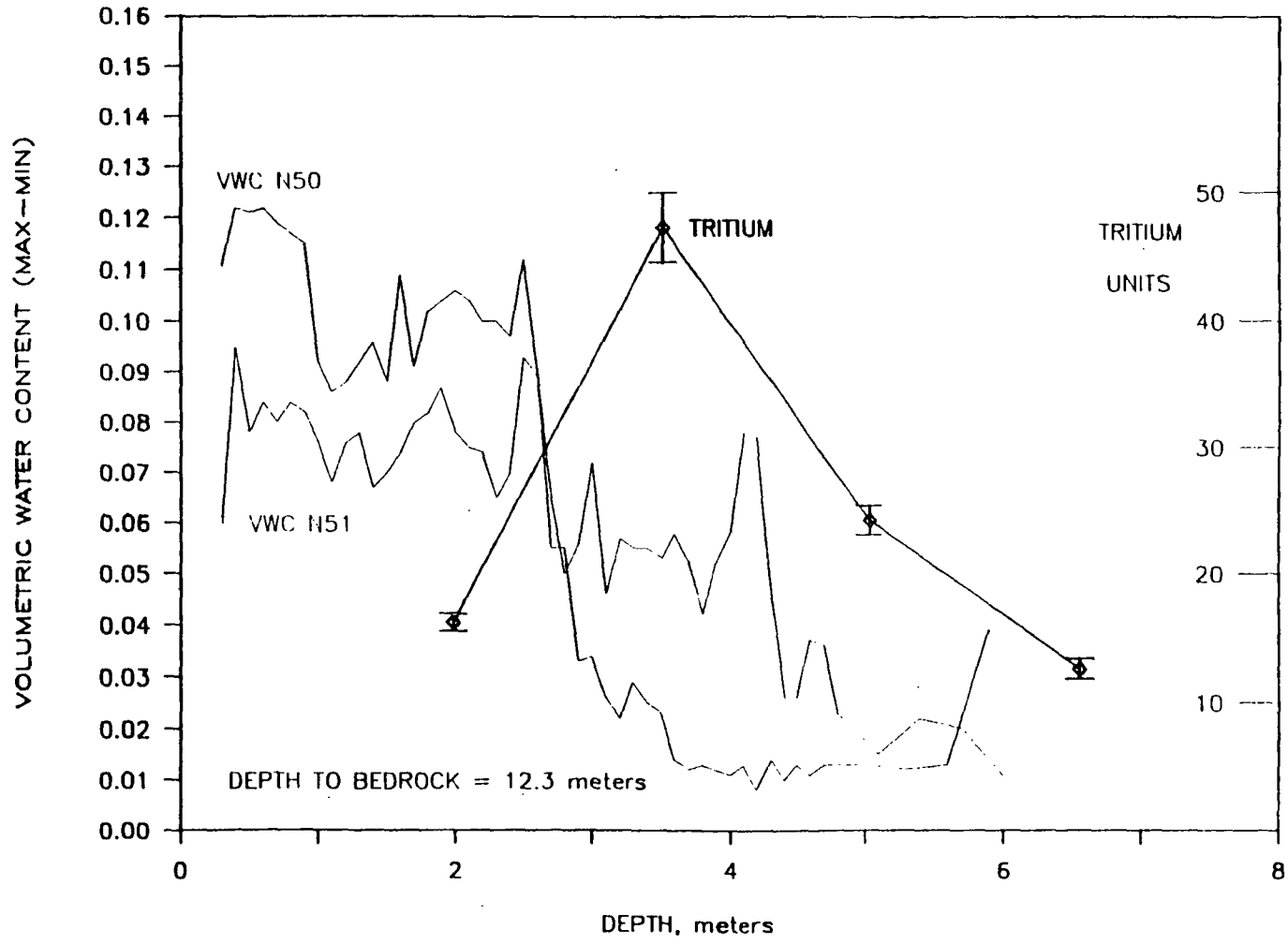

TRITIUM UNITS
UNITS
18
21
7
2
2
28
3
32
37
45
45
24
0
QTac
Tpc
BT
Tpy
BT
Tpp
BT
1000yr 14C H2O
Tpt
5000yr 14C H2O
UE-25 UZ4
WELDING
QTac
D
M
N-P
N
BT
N
P
N
BT
N
N-P
BT
N
D
N
ALT & XTL
METERS
QTac
D
A
BT
V
BT
V
BT
V
D
VP
0
10
20
30
40
50
60
70
80
90
100
110

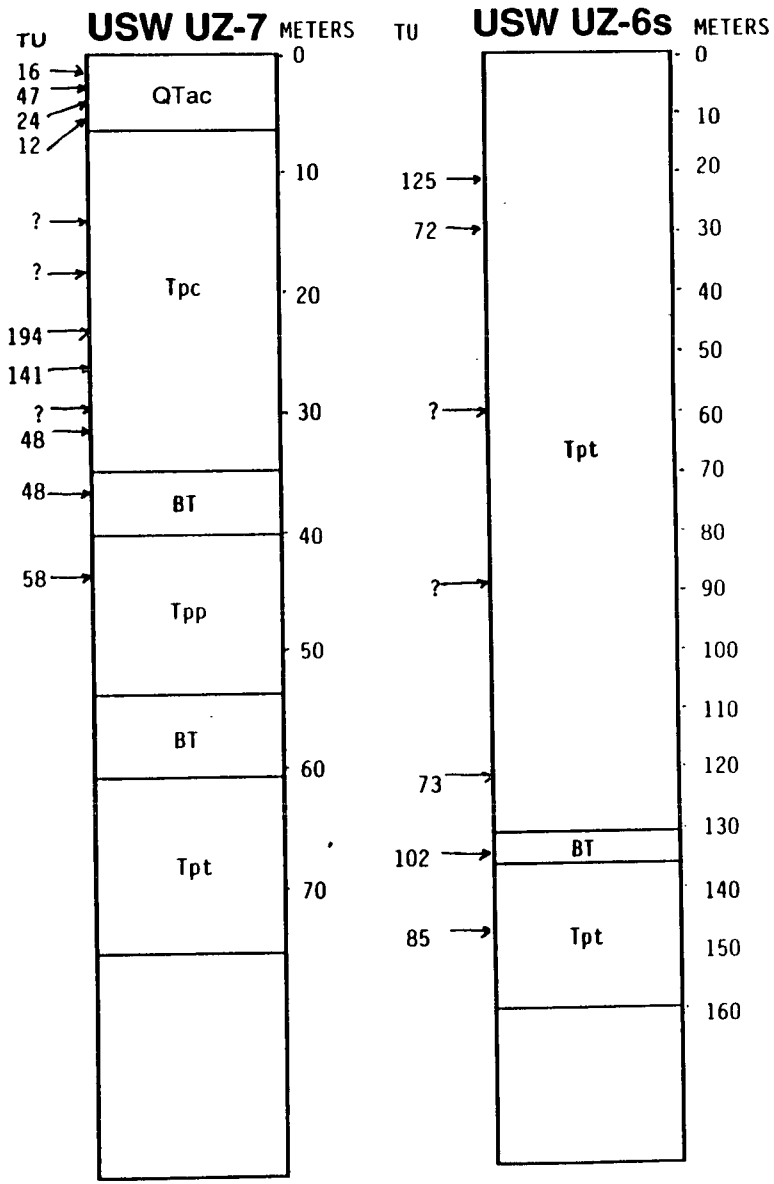
CROSS SECTION FROM UE-25 UZ4 TO UE 25 a#3



SCALE: 1" = 200'

UZ-7


VOLUMETRIC WATER CONTENT (MAX-MIN)
0.16
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
VWC N50
VWC N51
TRITIUM
TRITIUM
UNITS
50
40
30
20
10
DEPTH TO BEDROCK = 12.3 meters
0
2
4
6
8
DEPTH, meters


USW UZ-7
TU
METERS
16
47
24
12
?
?
194
141
?
48
48
58
QTac
Tpc
BT
Tpp
BT
Tpt
0
10
20
30
40
50
60
70
USW UZ-6s
TU
METERS
125
72
?
?
73
102
85
Tpt
BT
Tpt
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160

PHOTOGRAPH:
YUCCA CREST AND UZ6S LOOKING NORTH FROM SOLITARIO CANYON

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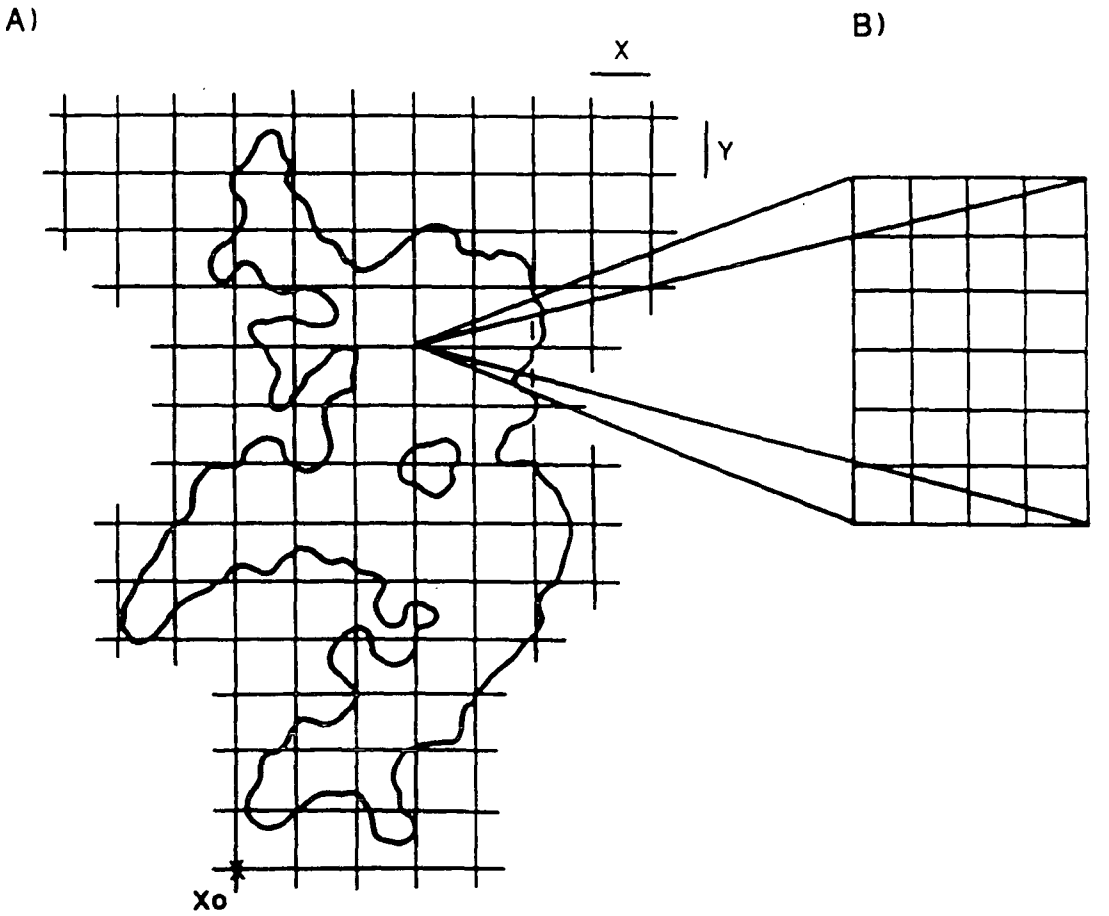
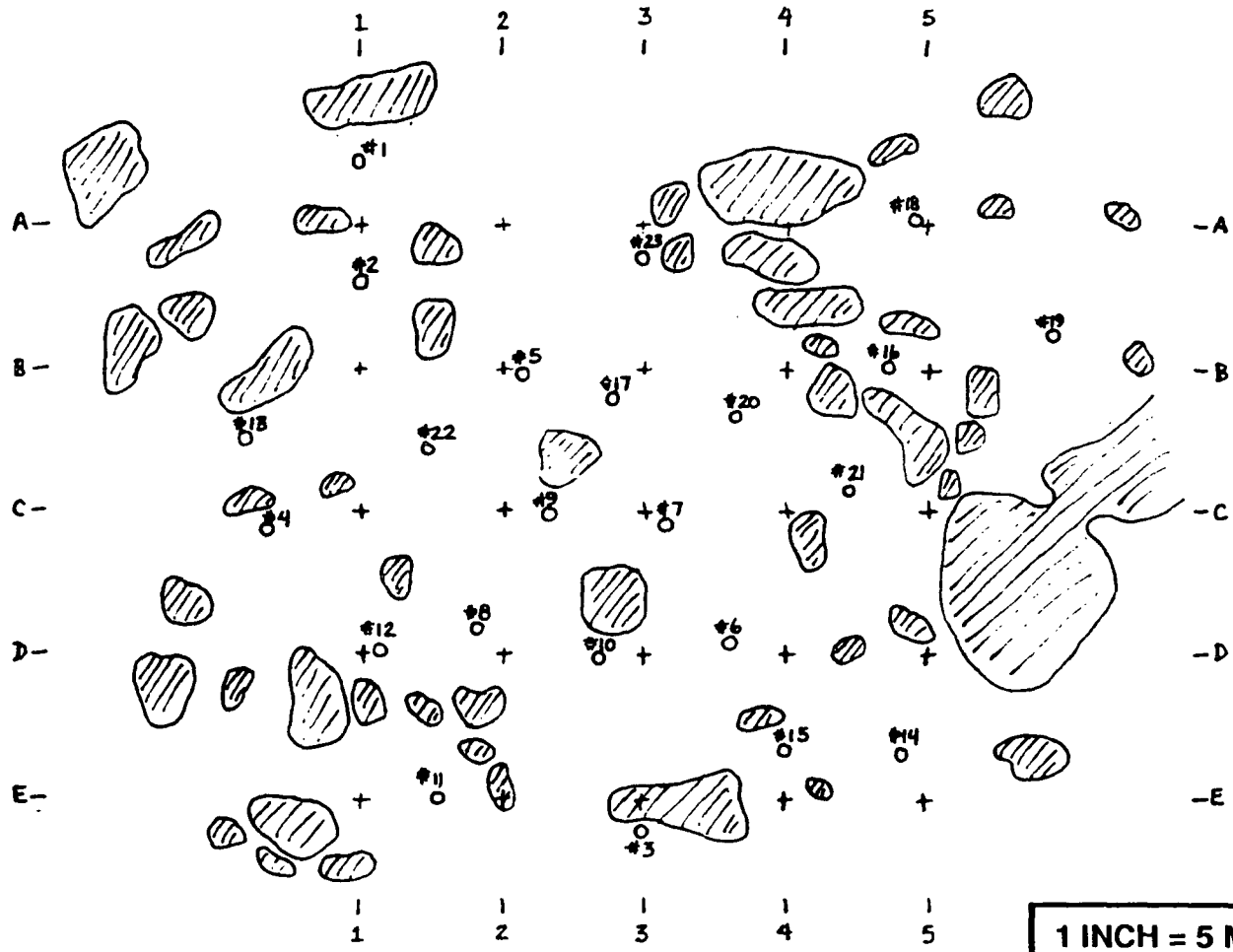


MAP SHOWING PROPOSED GRID SYSTEM FOR HYPOTHETICAL SURFICIAL UNIT (A) WHERE Xo IS THE REFERENCE POINT (0.0). A SINGLE, CENTRALLY LOCATED POINT WILL BE SELECTED FOR INTENSIVE, CLOSED-SPACED (5x5m) SAMPLING (B)

PRELIMINARY MAP -
DOUBLE CAP INFILTROMETER - YUCCA CREST

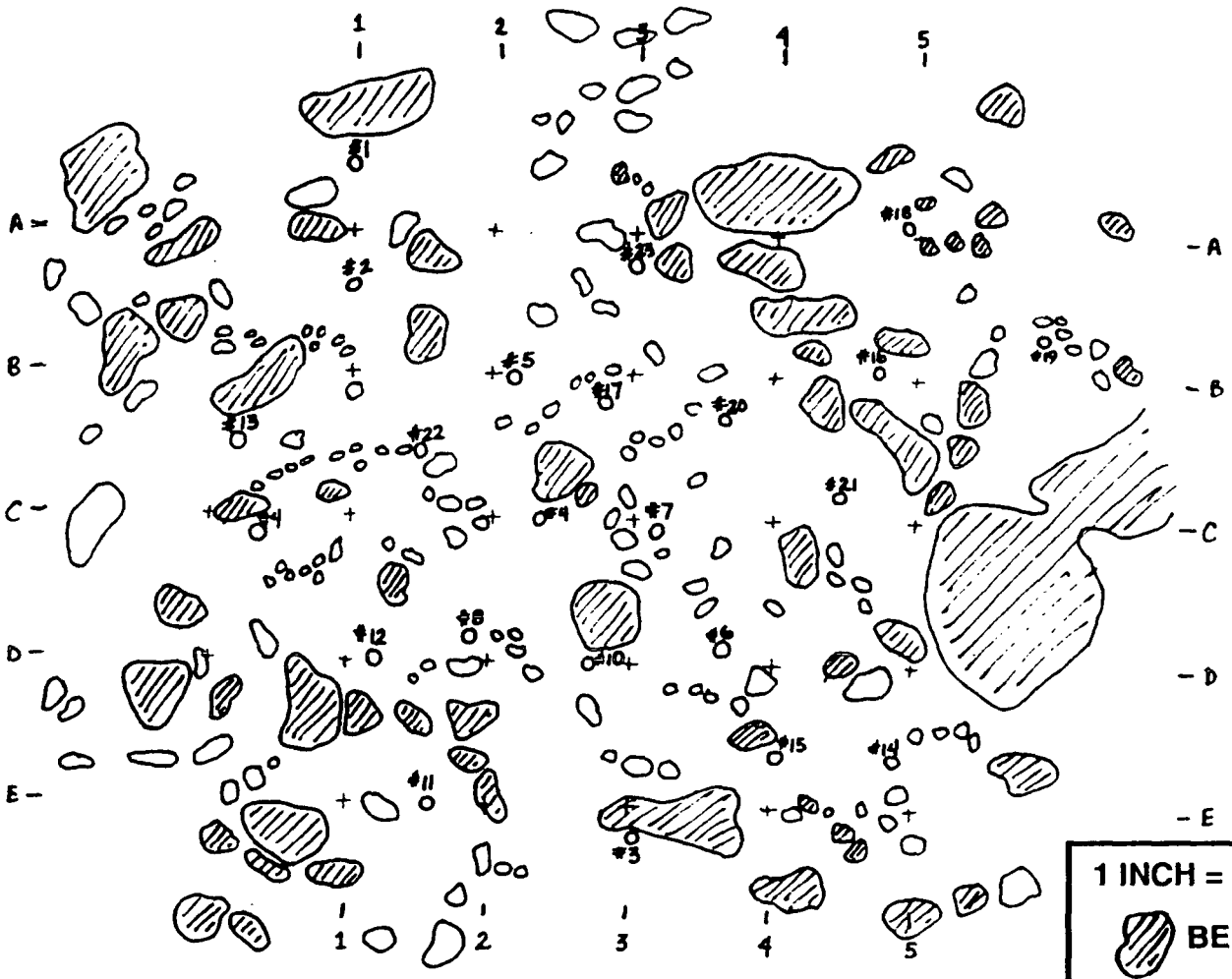


1 INCH = 5 METERS

BEDROCK OUTCROP

INFILTROMETER SITES

DOUBLE CAP INFILTROMETER MAP - YUCCA CREST



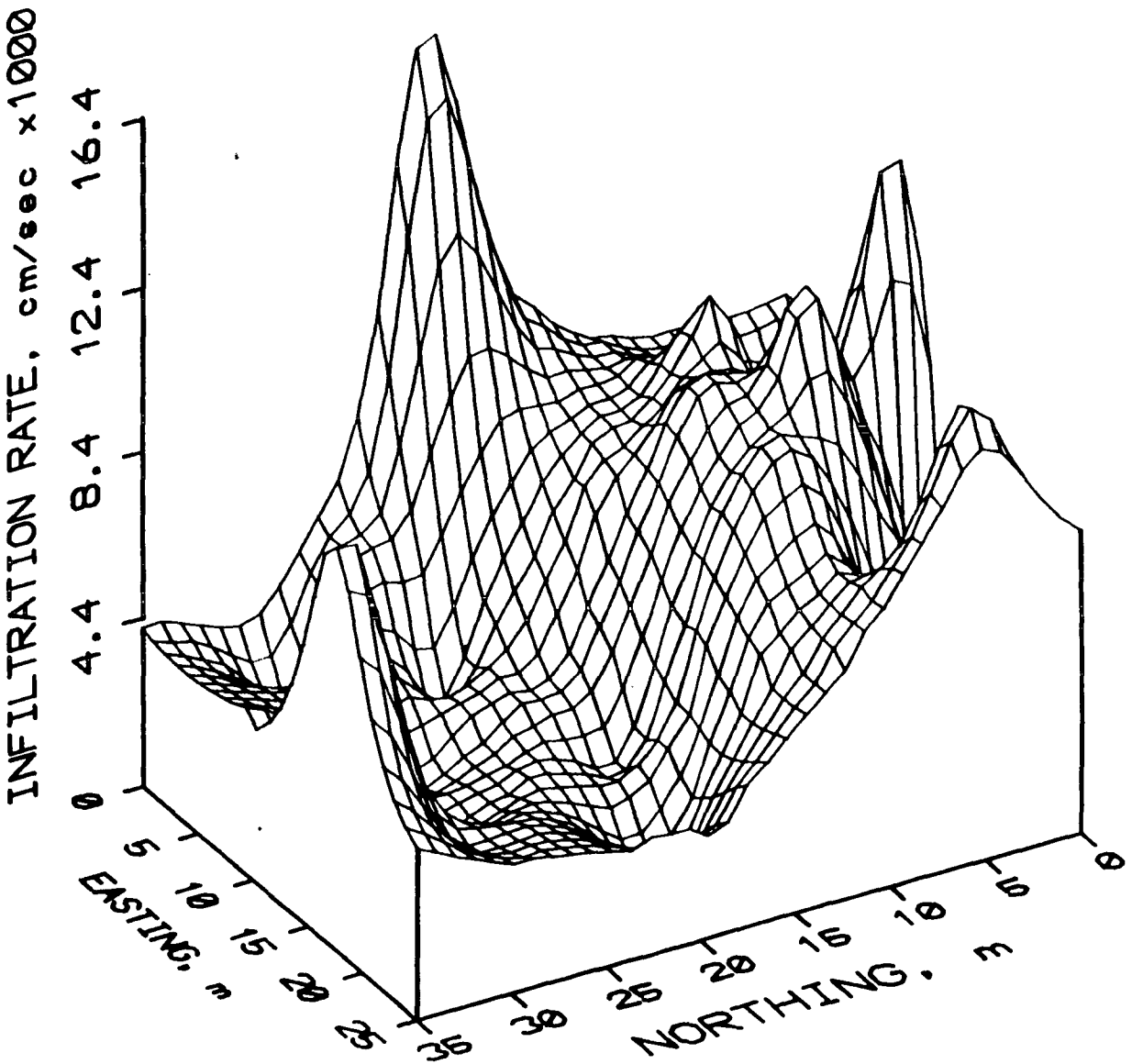
K_T
$\bar{x}$ 6.1 x 10^{-3} cm/s
sd 4.9 x 10^{-3} cm/s

N

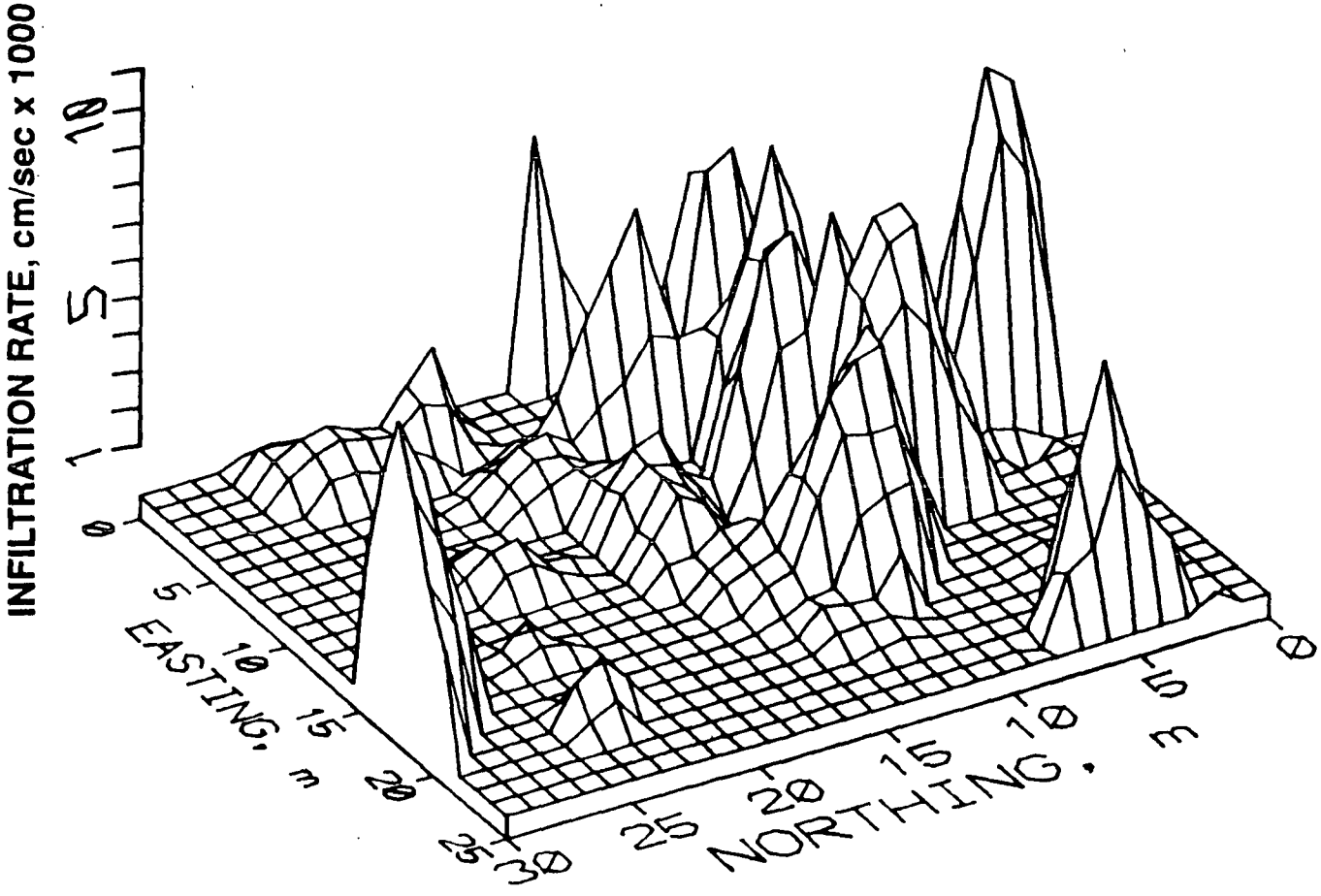
1 INCH = 5 METERS

- BEDROCK OUTCROP
- LOOSE ROCK
- BULK DENSITY SAMPLE LOCATIONS
- #1 INFILTROMETER SITES

INFILTRATION AT YUCCA CREST SMALL INFILTROMETER STUDY SITE



INFILTROMETER STUDY AT YUCCA MOUNTAIN USING OUTCROPS



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SUMMARY

- INFILTRATION IS SPATIALLY AND TEMPORALLY VARIABLE
- MORE DATA IS NEEDED ON A SPATIAL AND TEMPORAL SCALE
- REFINEMENT OF DATASET AND CONCEPTUAL MODELS IS AN ITERATIVE PROCESS

GENERALIZED TOPOGRAPHIC SETTINGS
GENERALIZED HYDROGEOLOGIC CONDITIONS